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Dr. Albert Haller's

PHYSIOLOGY;

BEING A

Ridout

COURSE of LECTURES

UPON THE

VISCERAL ANATOMY and VITAL
OECONOMY of HUMAN BODIES:

INCLUDING

The lateſt and moſt conſiderable DISCOVERIES and
IMPROVEMENTS, which have been made by the
moſt eminent Profeſſors, through all Parts of
EUROPE, down to the preſent Year.

Compiled for the Uſe of the UNIVERSITY of GOTTINGEN; now illuſtrated with uſeful *Remarks*; with an *Hiſtory* of Medicine; and with a *Noſology*, or Doctrine of Diſeaſes.

IN TWO VOLUMES.

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DEPOSITED
IN INST.
HIST. MED.

Vault

F.M.II.VI.53.

Benigno Scrutinio
Celeberrimi Archiatri
ALBERTI ab HALLER
Egregii hujus operis auctoris;
Regiæ Majeſtatis Britannicæ
Electoralis Hannoverienſis
Conſiliarii Aulici, & Archiatri:
in
Academiâ Gottingæ florentiſſimâ
Medicinæ, Anatomiæ, Chururgiæ,
Botaniceſque Profeſſoris publici, ordinarii, Ejuſdemque
Chirurgorum Collegii Præſidis
in
Academiâ Curioſorum Imperiali,
Etiamque in
Societatibus Scientiarum Regiis
Boruſſiæ, Gottingæ, Swetiæ, Upſaliæ,
Pariſienſi, Londinenſi, &c.
Conſocii plurimum venerandi;
nec non
In ſupremo Senatu Reipublicæ
BERNENSIS
Ducentum Viri:
in
Omnibus Linguis Europæanis
Lectiſſimi,
Noſtrâque Anglorum Peritiſſimi;

Omnibus
In Litteris Humanioribus, Scientiiſque
Callentiſſimi ;
ſed
In ampliſſima Facultate propria, ubique & fere
ad miraculum
Perdocti :
HÆC
In linguam Britanniæ vernaculam egregii ſui
Operis converſi
EDITIO,
Humilimè offertur,
D. D. D.
Servo ſuo addictiſſimo
SAMUELE MIHLES
Acadæmiæ Glaſguenſis Doctore Medico
Collegiique Regii Medicorum Londinenſium
Diplomate Permiſſio.

TO THE

READER.

ALL faculties, arts and ſciences, are allowed by the ableſt judges to be unavoidably ſubject to ſuch changes by time and after-improvements, as plainly render a new digeſt or ſyſtem of them equally uſeful and neceſſary, once at leaſt within a quarter of an age: and it would be well if our many annual abortives, that ſerve chiefly to perplex beginners, or baniſh better ſyſtems, could within theſe bounds be reſtrained. The ſpace preſcribed, has indeed twice elapſed ſince the appearance of ſuch a digeſt, from under the quill of the ingenious Dr. James Keill, and that of Dr. Drake; and it is now near a fourth of an age ſince the lectures of our great Dr. Boerhaave, were by him collected: all which performances being drawn by maſterly pencils, were indeed excellent for their day, and ſuch only as can pretend to ſhare any competition with the preſent ſyſtem. A reading of Dr. Boerhaave's lectures, formerly publiſhed by our author in Latin, and by ourſelves in Engliſh, may conduce to explain many particulars more largely to weaker capacities than could be done within this compaſs; but thoſe who are tolerably read in the faculty, may learn hence not only the ſum and ſubſtance of thoſe more voluminous lectures, but alſo numberleſs important and uſeful diſcoveries, made within the fourth of an age paſt, ſince thoſe lectures were cloſed; communicated to the public by our learned author, and other eminent profeſſors in ſeveral parts of Europe. To render our author's ſenſe juſt and plain, has often required more words than occur in the original; but 'tis more eligible to be well underſtood in two or three words, than to be doubtful or obſcure in one. We have alſo taken the liberty to inſert a number of conſiderable remarks, either philoſophical or practical, as our own obſervations ſuggeſted them in the courſe of our verſion; which with the Hiſtory and Noſology, have indeed ſomewhat increaſed the bulk and price of the ſyſtem, but neither, we hope, beyond proportionable meaſures of uſeful inſtruction and practical utility: at leaſt our views in the whole were only to employ our leiſure hours in recommending the beſt means we know, to the hands of thoſe who deſire to gain a true and uſeful knowledge of their profeſſion, in the moſt plain, juſt, and eaſy manner.

S. M.

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PHYSIOLOGIA;

OR, A

COURSE of LECTURES

ON THE

VISCERAL ANATOMY and LIVING OECONOMY of the HUMAN BODY, &c.

LECTURE I.

Of the Animal Fibres.

§. 1. THE moſt ſimple parts of the human body are either fluid or ſolid. The fluid parts being of divers kinds, we ſhall hereafter conſider in their moſt convenient places. But here the ſolids, which make the moſt ſimple and true baſis of the body, come firſt to be conſidered before the hiſtory of the other parts.

REMARK.

A *body*, philoſophically ſpeaking, is any extended and reſiſting object of our ſenſes; whoſe parts have more or leſs an attractive and coheſive force one to another. If this coheſion betwixt the parts are ſtrong enough to keep them in their ſituations (contrary to the force by which they tend to the earth's center) and preſerve the natural figure of the body, we call it a *ſolid*; but if this coheſion be ſo weak that the gravitation of parts brings them to a level, or to a portion of the earth's convexity, when left to themſelves, we call it a *fluid*; but if the coheſion of parts be neither ſtrong enough to retain the figure, nor weak enough to let them flow to a level, we call the body *ſoft*, in various degrees 'till you come to the coheſion of a ſolid, beyond which we count *hardneſs*. Hence we ſee, that, by leſſening the coheſion and contact of parts, the ſame body may be either ſolid, ſoft or fluid; as, e. g. Reſin or butter with different degrees of heat, leſſening the attraction of coheſion in the conſtituent particles.

§. 2. The ſolid parts of animals and vegetables have this fabric in common, that their elements, or the ſmalleſt parts we can ſee by the fineſt microſcope, are either fibres, or an unorganized concreet.

REMARK.

(1.) Elements are the ſmalleſt and moſt ſimple particles we can deſcend to in the compoſition of bodies. And theſe, which we are to conſider as the keys of nature, are ſuch as we are either led to by ſenſe and reaſon, or by reaſon only. Theſe laſt are, therefore, termed ontological elements or primitive atoms, from their firſt obſerver Democritus, in contradiſtinction to the four common or phyſical elements of Ariſtotle. For though matter be in the mind infinitely diviſible, 'tis not actually ſo in nature, but to a certain degree. And from theſe indiviſible or atomical particles, differing only in bulk and figure, by a various combination, ariſe thoſe ſenſible or univerſally extended homogeneous bodies we call phyſical elements, becauſe we ſee nature uſes them by mixture, texture and organization to form all the bodies in the univerſe. Such are the infinite expanſion of *æther*; our limited ſphere of *air*; the more confined body of *water*; and that ſtill leſs body which we call *earth*.

(2.) ÆTHER is that compound, ever highly elaſtic and ſubtileſt of all fluids, which is extended by reciprocal undulations throughout the univerſe (our vacuum's or exhauſted glaſſes not excepted) ſo as (by moving with a certain celerity in direct lines) to form *light*; by reflection and refraction, *colours*; by attraction and colliſion with the other elements, *heat* and *fire*, leſs degrees of which we call *cold*.

(3.) AIR is that diaphanous and compreſſible fluid which is extended about a degree round the terraqueous globe, being with us about 46,656,000,000 times more denſe and ſluggiſh than æther, betwixt which and air there is a very great affinity or attractive force, as their denſity; i. e. the air contiguous to the æther takes in and concentrates the æther proportionally to its greater denſity, by which it is rendered more ſpringy and active, with this difference that the air, by contact and coheſion in the parts of bodies,

dies, becomes ſolid and unelaſtic (but æther never); from whence again, by heat, fire or diſſolution of parts being ſeperated, its elaſticity returns. This element has a near affinity or relation to water, becauſe it eagerly takes up rarified water into itſelf, as water again drinks up a portion of air within its contact; ſo that air and water, actuated by æther, make the levers and wedges by which nature performs all her changes in bodies either ſynthetically or analytically. And it ſerves as the common medium of communication betwixt us and all bodies.

(4.) WATER is a colourleſs, inſipid, inodorous and uninflammable liquor, ſtrongly related or of near affinity both to air and earth, but more particularly the laſt, ſince it readily abſorbs them, as they abſorb it. This owes it fluidity to a certain degree of heat, ſince with a heat, two thirds leſs than that of our blood, it congeals; and with about twice the heat of our blood it boils, beyond which it can be made no hotter.

(5.) EARTH, as an element, is a ſolid, opaque, angular, friable, chalky ſubſtance of ſuch ſmall volatile particles, that it readily diffuſes itſelf through air and water, and reſides inviſibly in them; as earth eagerly imbibing both air and water, by their means forms the permanent baſis and growth of all mineral, vegetable and animal bodies.——A ſmall particle of æther, air and water combined will, from their fluidity, form a ſpherule, conſequently inſipid and inodorous; but coming into ſtrict union, round a more denſe, angular particle of earth, will be a conoide corpuſcle, of which the ſpherule will be the baſis, and the leaſt point of the earth the apex. Such a particle, irritating the ſmell and taſte by its figure and denſity, volatile from its minuteneſs, and ſtrongly attracting both air, water, and earth, (eſpecially the laſt) we call an acid, fluid *ſalt*. And ſuch parts again variouſly combined with light earth and the other elements, will form a bituminous, greaſy, ſulphurous or oily ſubſtance, combuſtible or inflammable, as Sir I. Newton obſerves. Thus mineral elements, ſalts and ſulphurs taken from the earth, do, by heat and organiſation, become vegetable in plants; thoſe of plants are changed into animals, and thoſe of animals into one another, without ever carrying the diſſolution to the minima naturalia, or atoms of Democritus. An acid is thus by the reed neutraliſed into ſugar; in the common radiſh, pellitory of the wall, &c. 'tis made nitrous; in the horſe-radiſh, onion, &c. alcaline; and alcalies, (ſoot, pot-aſh, rotten fleſh) are again in the vine and grape changed firſt into a ſour and then into a ſaccharine juice, &c. ſo that out of a few ſimple elements (as in the notes of muſic) by combinations ariſe all the varieties of medicinal and other ſubſtances. Theſe combined by mere mixture and contexture, as in minerals, ſalts, gums, cartilages, glue, &c. make an unorganiſed concreet; but when the parts combined perform any motion in a living body, whether plant or animal, we call them a machine, or if complex an organ; of which fibres or flexible elaſtic threads are the moſt ſimple, and univerſally compoſe the reſt. So elaſtic globules, with a watry albumen or gelly, are the baſis of all the circulating juices, that of the nerves not excepted.

§. 3. A fibre in general may be mathematically conſidered as reſembling a line made of points, having a moderate breadth; or rather geometrically as a ſlender cylinder. And that the more conſtant or permanent parts thereof are earth, is demonſtrated from a calcination, or a long continued putrefaction.

REMARK.

An animal or human body is not improperly ſaid to be made up of clay or ſlimy earth, ſince all the ſolids (which are compoſed of fibres) and even the permanent or globular fluids which circulate, are formed of chalky particles like thoſe of pipe-clay cemented together by glue or gelly; as you may ſee by burning a lump of blood or a bone in a clear fire, where after the air, water, ſalt and oil, which compoſe the glue, are expelled and conſumed, you have a white, friable, chalky earth, coming the neareſt to virgin or elementary earth of any we know. So likewiſe by diſeaſe or putrefaction in a ſpina ventoſa of the bones. And we ſee theſe *ſtamina* or gluey particles of earth, which compoſe all the minute, ſolid and fluid machinulæ of the body, are prepared from our ingeſta paſſing not only the chylificative, ſanguineous and ſerous veſſels, but alſo for ſome parts through the brain and nerves, before they are applied as nutritious matter; requiring a healthy ſtrong ſtate both of veſſels and humours to duly prepare them as to ſize, quantity and quality, as well as to apply them, (a defect of which we ſee in rickets, ſcorbutic, venereal, caſes); whence 'tis ſomewhat ſtrange our great Boerhaave ſhould in his 21ſt practical aphoriſm, conceive them as immutable in their ſoft glutinous ſtate within our bodies, as in the dry rigid condition of a goldſmith's cuppell, after paſſing the fire.

§. 4. Theſe earthy particles have their connexion and power of coheſion not from themſelves, or a mere contact, but from the intermediate glue placed betwixt them. This we know from the experiments mentioned above (§. 3.); and from the eaſy experiment by which a burnt hair, whoſe parts yet hang together, recovers a degree of firmneſs by dipping in water or oil. Alſo the remains of ivory or bone ſhavings, whoſe gelly has been extracted, become friable.

REMARK.

Theſe experiments ſufficiently prove that the degree of coheſion in the parts of a fibre by which 'tis ſaid to be ſtrong or weak, lax or rigid, depends chiefly on the quantity and tenacity of the intermediate connecting glue.

§. 5. That this glue is compoſed of oil combined with water by the vital attrition in animals, appears again from the chemical analyſis of bones and hair; from the jelly of bones, ivory, and horns; and from the nature of our aliments themſelves. Nor is there any kind of glue that could more powerfully join the parts of animals together; as we experience in fiſh-glue, and that of joiners or cabinet-makers, &c. See §. 15. ult.

REMARK.

Add that this oil is diſpoſed to unite with the water by attrition from a conſiderable portion of an ammoniacal or neutral ſalt joined with a good deal of unelaſtic air; which ſalt we obtain in an alcaline volatile ſtate by diſtillation.

§. 6. Earthy particles then (§. 3.) cohering longitudinally, and tied together by an intervening coheſive glue, (§. 5.) compoſe firſt one of the leaſt or moſt ſimple fibres; ſuch as we have a knowledge of rather from reaſon than ſenſe.

REMARK.

The fineſt microſcopes have been hitherto inſufficient to lead us to a ſight of the ſmalleſt moving and nervous fibrils, and ſtill leſs can we ever expect from them to get any ſenſible idea of the mechaniſm by which ſenſation and motion are effected. For how motion is modulated to produce animal ſenſe, or how animal ſenſe and will can produce motion, we can only conjecture, and never certainly know. We proceed, therefore, to compound viſible fibres.

§. 7. But the leaſt fibres which appear laſt to the ſight, if you will take up with their firſt appearance and the eſtabliſhed opinion, are of two kinds.

REMARK.

From the figure of theſe two kinds of fibres, as we ſhall preſently ſee (§. 8, 9.) we may diſtinguiſh the former by the title of filamentary, and the latter of membranous.

§. 8.

§. 8. The firſt kind of theſe fibres (§ 7.) is lineal, namely, ſuch a form as makes their length conſiderably large in proportion to their breadth; and which, by diſpoſing of the elementary particles in a right line, muſt of courſe lay them generally parallel with the neighbouring or contiguous fibres. Examples of ſuch fibres we ſee in the bones, and moſt eaſily in thoſe of a fœtus; and likewiſe in the tendons, ligaments and muſcles: only we muſt here always remember, that the eye never reaches to the ſmalleſt fibres, but to larger ones made up the ſmalleſt, and like to them in ſlenderneſs, placed together in a rectilineal courſe. That theſe are not different from the ſmalleſt fibres, we are perſuaded by the moſt accurate microſcopes of Muyſe and Lewenhoeck; by which, the muſcular fibres divided even to the laſt, appear ſimilar to the larger, till, at length, they ſeem mere lines, like ſpiders threads.

§. 9. The ſecond kind of fibres (§. 7.) are thoſe which are conjoined with a breadth frequently larger than their length, in forming what is commonly called the *cellular* tunic or membrane; tho' the name tunic or membrane is on many accounts improperly given to it.

REMARK.

From what has been ſaid, we may admire nature no leſs for her wiſe œconomy than ſimplicity, in thus forming all that variety of parts we ſee in an animal from one ſimple maſs of clay or ſlimy matter, compounded of earth and glue; from whence the body is not only augmented from a ſingle point in the ovum to its full growth and ſtature; but, like the timbers of a ſhip, is alſo every day repaired during life, 'till, at length, not two jots of the old or firſt materials remain. This renovation of parts is made ſlower in ſome conſtitutions, and in ſome organs, than in others. How quickly the animal humours with the hair, nails, &c. are renewed every one knows: and we may venture to ſay, that once in three years the change is univerſal; at the end of which time, tho' a man remains the ſame identical perſon, he is not the ſame matter.—— But we proceed from theſe ſimple fibres to the next leaſt compounded ſolid which they compoſe, viz. the *tela vel ſubſtantia celluloſa ſpongioides*, the cellular web-like ſubſtance.

§. 10. The ſaid cellular ſubſtance is made up partly of the forementioned ſimple fibrills (§. 8, 9.) and partly by an infinite number of little plates or ſcales, which, joined in various directions intercept ſmall cells and web-like ſpaces; and by extending round every, even the leaſt moving ſolid parts of the body, conjoins them altogether in ſuch a manner as not only ſuſtains, but allows them a free and ample motion at the ſame time. But in different parts of the body we obſerve a great variety of this web-like ſubſtance, in reſpect of the proportion betwixt the membraneous ſides and intercepted cells, as well as the breadth and ſtrength of thoſe ſides, and the nature of their contained liquor, which is ſometimes more watry, and ſometimes more oily.

REMARK.

The extenſion of this ſubſtance, not only with the ſkin round the whole body, but alſo round every viſcus or organ, and round every individual moving fibre or veſſel of them, into the cavities of the bones, and even the ſubſtance of the brain and its medulla, is a modern and wonderful diſcovery of anatomiſts, by which we have great light into many otherwiſe obſcure diſeaſes. This ſubſtance in its ultimate or fineſt ſtate being compoſed of ſimple membranes, when compacted and convoluted, gives birth to the leaſt or moſt ſimple veſſels, which, again reflected through plates of the ſame ſubſtance compacted together, make compound and vaſcular membranes, to the conſideration of which we next proceed.

§, 11. Out of this net-like cellular ſubſtance compacted by a concretion of the membranous plates or partitions, and preſſed together by the force of the incumbent muſcles and diſtending fluids, ariſe other broad and flat plates or ſkins in various parts of the body, which being generally diſpoſed in one and the ſame direction, ſeem to have yet a better right to the title of membrane, than the former; and theſe being convoluted into cones and cylinders, pervaded by a flux of ſome juice or liquors brought to them, put on the name of *veſſels*, or elſe being extended round ſome ſpace that is in a plane parallel to itſelf, we call it a *tunic* or coat. But that tunics or coats are formed out of the cellular ſubſtance is proved to ocular inſpection, eſpecially in the aorta or dura-mater, by maceration; and the coats of the muſcles are thus evidently of a cellular fabric, while they reſemble the texture of other membranes; from a degeneration of the pericardium as a true membrane into the cellular ſubſtance, or membranes of the great blood veſſels belonging to the heart; from the origin of the hard and thick membranes which are about encyſted tumors, and which are formed only in the cellular ſubſtance; laſtly, from the eaſy change of the dartos coat of the teſticle, and the nervous tunic of the inteſtines, by inflation, into the cellular fabric.

§. 12. All the veſſels with which we ſee tunics commonly painted, are an addition to the cellular net-work, and in no wiſe conſtitute the nature of a membrane, but are ſuperadded to the membrane itſelf, which is firſt formed of the cellular net-like ſubſtance. Betwixt the maſhes or ſpaces of the inteſtinal net-work of veſſels, perfectly well filled by the Ruyſchian art of injection, we ſtill ſee that the white cellular ſubſtance which remains, greatly exceeds the bulk of the veſſels, although, by their preternatural diſtention, they take up more room by filling more of the ſpace. But for membranes compounded of fibres, interwove or decuſſating each other, I know of none ſuch, unleſs you will take ligamentary or tendinous fibres for them, which yet are ſpread only over the face of ſome true membrane.

§. 13. This cellular web-like ſubſtance in the human body is found throughout the whole; namely, wherever any veſſel or moving muſcular fibre can be traced, and this, without the leaſt exception, that I know of, in any part whatever. See remark of §. 10. and of §. 17. following,

§. 14. The other elementary ſubſtance of the human body (§. 2.) viz. *concrementum glutinoſum chondroeides*, which cannot be truly called either a fibrous or cellular plate, is a mere glue evaſated and concreted, not within the fibres, but in ſpaces betwixt them. In the bones this extravaſated ſubſtance is manifeſt enough; for you ſee the fibres very diſtinct in the bones of a fœtus, in the intervals betwixt which you perceive the veſſels running; ſo that every bone in the ſkull on all ſides reſembles the teeth of a comb. But this fabric is ſo altered in an adult perſon, that a cartilaginous juice being extravaſated in the ſpaces betwixt the fibres, we ſee ſmall plates formed of it.

§. 15. But here the courſe of nature ſeems to be ſuch, that even the filamentary fibres (§. 3.) are all firſt formed of ſuch a transfuſed glue. And that the membranous or ſcaly fibres of the cellular ſubſtance (§. 7.) are thus formed appears, from thoſe cellular fibres produced in the thorax from a concreted vapour or ſerum transfuſed through the ſurface of inflamed lungs, which are thereby conjoined to the pleura; for theſe perfectly reſemble the true and natural cellular ſubſtance. The ſame appears alſo from a compariſon of the fœtus with an adult; for the large ſubcutaneous cellular ſubſtance has in a fœtus a mere jelly in its ſtead interpoſed betwixt the ſkin and muſcles, which laſt we obſerve very firm in a fœtus. This theory is again illuſtrated (1.) *ſynthetically*, by the fibrous cake one may draw out from blood by ſtirring it round with a probe; and from the membrane, which may be in like manner formed thence according to the experiment of Ruyſch, and Albinus's membrane from mucus; laſtly, from the formation of a polypus, ſilk and glue. (2.) *Analytically*, we ſee, from diſeaſes, that the bony fibres are formed firſt of a compacted glue; becauſe the hardeſt bones, by a diſſolution of their glue, return again into cartilage, fleſh, and jelly: ſuch experiments we make on the bones of fiſh and other animals with Papin's digeſtor.

§. 16. The *anthropogeneſis*, therefore, or formation of the human ſolids, ſeems begun when a gelatinous water, like the white of an egg, with a ſmall portion of fine cretaceous earth, runs together into a thread, from ſome preſſure, the cauſes of which are not our preſent concern. Such a filament, by the mutual attraction of coheſion, intercepting

ing ſpaces betwixt itſelf and others, helps to form a part of the cellular net-like ſubſtance, after having acquired ſome toughneſs from the neighbouring earthy particles, which remain after an expulſion of the redundant aqueous glue. And in this net-like ſubſtance, wherever a greater preſſure is impoſed on its ſcales or ſides, they turn into fibres and membranes or tunics; and in the bones, laſtly, they concrete with an unorganiſed glue. (§. 14). Hence, in general, all parts of the body, from the ſofteſt to the hardeſt, ſeem to differ no otherwiſe than as the former have more of the earthy particles more cloſely compacted together, with leſs of the aqueous glue; while in the ſofteſt parts there is leſs earth, and more glue. See the remark of §. 3.

LECTURE II.

Of the cellular ſubſtance and its fat.

§. 17. WE have now ſeen (§. 10.) that the cellular web-like ſubſtance is made up of fibres and plates, which are neither hollow nor vaſcular, but ſolid; although they are afterwards painted by an acceſion of veſſels. But the principal differences of its fabric are the following. In ſome parts of the body it is open and looſe, being formed of long and diſtant plates; in others, it is thin and compact, being made up of ſhort fibres, concreted together. I find it thineſt and of the ſhorteſt fibres, betwixt the ſclerotica and choroides of the eye; and betwixt the arachnoides and pia mater of the brain. I alſo find it very thin, but more tender and conſpicuous, betwixt every two coats of the inteſtines, ſtomach, bladder and ureters: 'tis alſo thin and empty under the ſkin of the penis, forehead, and in the lungs, in which laſt we call it veſicles. 'Tis compoſed of yet longer fibres, where it is extended over the larger veſſels, under the name of a capſule or vagina; as through the viſcera, and particularly the liver and lungs. Its principal uſe is to bind together the contiguous membranes, veſſels and fibres in ſuch a manner as to allow them a due or limited motion. But the cellular ſubſtance, ſo far as we have hitherto deſcribed it, hardly ever admits of any fat into the cells; which are rather moiſtened by a watry vapour, that is ſomewhat gelatinous and oily, exhaled out of the arteries and received again into the veins. The truth of this is eaſily demonſtrable from injections of oil and water, either alone or with fiſh-glue, made in all parts of the body. When this vapour is, by inflammation, too glutinous, or, from any cauſe, abſent or aboliſhed, the ſmall fibres grow one to another, and the contiguous membranes or plates are cemented into one, with a loſs of their motion.

§. 18. The cellular ſubſtance and its plates or ſcales, are ſtill more looſe and open where it divides the muſcles and all their fibres (even to the ultimate fibre); and likewiſe where it ſurrounds and ſuſtains the leaſt veſſels with their free motion. That within the cavities of the bones is alſo made up of bony plates, with membranous ones intermixed; and laſtly, it is the moſt looſe and open of all, round the ſurface of the body on all ſides, betwixt the muſcles and the ſkin.

§. 19. Into the empty ſpaces of this cellular ſubſtance, (§. 18.) almoſt every where, in the fœtus is poured at firſt a jelly, and afterwards a fat; which at firſt is grumous or curdy, but afterwards clear and leafy; namely, a thick, inſipid, inflammable liquor, which, in a cold air, congeals, in ſome degree, into a ſolid, eſpecially about the kidneys of herbivorous and horned cattle; but is ſofter and yellower in carnivorous ones; and while they are living, it ſeems a mere fluid, or very nearly ſo.

§. 20. Through this cellular web-like ſubſtance the ſmall veſſels are ſpread and ramified in all parts of the body, from whoſe arterial extremities the fat is depoſited into the cells, and afterwards abſorbed by the venal orifices. This paſſage, from the arteries into the adipoſe cells, is ſo free and ſhort, that there muſt needs be very large mouths by which they open, and by which they give admittance to injected mercury, air, water, diſſolved fiſh-glue or jelly, and oil not excepted, which is always very ſluggiſh in paſſing through the veſſels, even of living animals. The oily fat, in this ſubſtance, is ſeperated and expelled from the artery, not by any long ducts, but by tranſuding on all ſides through the whole extent of the veſſel; inſomuch that when an artery is filled or injected with water, there is no part of the ſurrounding cellular ſubſtance, but what ſwells with the moiſture. How quickly it is collected from the arteries, appears from the ſpeedy renovation of it, by a returning fatneſs after acute diſeaſes. See §. 25.

§. 21. But this return of the fat abſorbed by the veins, we are taught from the ſudden effects which labour or exerciſe of the muſcles more eſpecially has in conſuming the oil of very fat animals; alſo from the conſumption of our fat in fevers, and from the cure of dropſies, where the water tranſfuſed into the cellular ſubſtance, is in a manner abſorbed and thrown out by the inteſtinal tube; and laſtly, from the tranſuding of water and oil from the venal orifices, when injected by the ſyringe. Whether any of the nerves pour out their contents into, or are ſpread upon, the adipoſe cells, is an improbable queſtion. But 'tis certain they in moſt parts run through this ſubſtance, and hereby divide, in their courſe, into the minuteſt filaments, ſo ſmall that you can no longer trace them by the knife. But then the fat is both inſenſible and unirritable.

§. 22. With regard to the ſponge-like communications of this ſubſtance, 'tis remarkable, the intervals or ſpaces betwixt the plates or ſcales that make up their ſides in the cellular membrane, are every where open, and agree in forming one continuous cavity throughout the whole body. This appears from the inflation which butchers make by a wound of the ſkin, and which being once received into this ſubſtance, is eaſily driven ſo as to raiſe the ſkin all over the body; and likewiſe from an emphyſema, in which the air received by a wound of the ſkin, being retained, cauſes a ſwelling throughout the whole ſurface of the body; and finally from diſeaſes, in which a watry or ſerous humour is depoſited into all the cells of this net-like ſubſtance, throughout the body. That none of the cellular fabric is excepted from this communication, appears from wounds or accidents, wherein even the vitreous body itſelf of the eye has received the flatus of an emphyſema; and again from diſeaſe, in which the gelatinous ſerum of a dropſy has been found transfuſed even into the cavernous bodies of the penis.

§. 23. The great importance and uſe of this cellular ſubſtance, in the animal fabric, muſt be evident to all who conſider that from this part alone proceeds the due and healthy firmneſs, ſtrength and ſtability not only of all the arteries, nerves and muſcular moving fibres of the body, but likewiſe of all the fleſhy parts and viſcera, which are made up of the former, folded together within this ſubſtance: and even the figures, cavities, pliability or flexures and motions of the ſoft parts depend entirely on the cellular membrane, in ſome places of a lax and in others of a more cloſe and hard fabric. That out of this ſubſtance joined with veſſels, nerves, muſcular and tendinous fibres (a great part of all which are before formed of this ſubſtance only) all the viſcera, all the muſcles and glands, with their ligaments and capſules, are entirely compoſed; and that only from the different length, tenſion, quantity or proportion of this the diverſity of our glands and viſcera ariſes; and laſtly, that this alone makes up by far the greateſt part of the whole body, as we are certain, although the whole be not formed out of cellular filaments of this kind.

§. 24. The *uſes* of the fat are various; as to facilitate the motions of the muſcles in all parts, leſſen their attrition againſt each other, and prevent a ſtiffneſs or rigidity; it fills up the intermediate ſpaces betwixt the muſcles in ſuch a manner, with the cavities about many of the viſcera, that it readily yields to their motions, and yet ſupports them when at reſt; it ſerves as a ſtratum or bed to conduct and defend the veſſels in their courſe to all parts; it gives an uniform extenſion to the ſkin, and ſerving as a cuſhion to eaſe the weight of the body in many parts, at the ſame time it renders the whole of a comely, agreeable ſhape: it probably by returning and mixing with many of the humours, abates their acrimony; it has a principal ſhare in forming the matter of the bile, and by tranſuding through the cartilaginous incruſtations of the bones, it mixes with the articular liniment or ſynovia; alſo by exhaling in a living perſon from the meſentery, meſocolon, omentum and round the kidneys, it lubricates the ſurfaces of the viſcera with an oily emolient vapour, and by interpoſing betwixt their integuments, prevents their growing one to another.

§. 25. The fat is depoſited into the cells of this ſubſtance by much ſleep, with reſt of body and mind; whence being collected in too great a quantity, it proves injurious by compreſſing the veins, and by cauſing too great a reſiſtance to the heart it makes a perſon ſhort-breathed and liable to an apoplexy or a dropſy. The ſame humour is repelled from the cells into the veins, and being rapidly moved along the arteries, the exceſſive motion will not allow it to go off laterally by the ſecerning pores to the cells: whether this celerity of the blood be, by violent exerciſe, watchings, cares of the mind, a ſalivation or a fever. Thus it cauſes an increaſe of acute diſeaſes, tinges the urine of an high colour, and forms a great part of its hypoſtaſis or ſediment. After a ſudden conſumption of it, 'tis ſoon renewed again from good juices, or healthy humours: but in a languid valetudinary habit, a gelatinous ſerum, inſtead of fat, is depoſited into the cells; and this cauſes the dropſy we call anaſarca, affecting the whole habit, together with an external hydrocele or watry ſwelling.

REMARK.

Hitherto we have ſurveyed the œconomy of nature in her wiſe formation of the moſt ſimple ſolid machinulæ of our body, namely ſuch parts as by their form and elaſticity are capable of a reciprocal action, ſo as to perpetuate for a number of years the motion that is once given them. Theſe we ſee ſhe has formed of the moſt permanent earthy particles incruſted with an oily glue; which as they are prepared by a continued undequal attrition of fluids through a numerous ſeries of veſſels, muſt receive a ſpherical figure*, that will be apt to change by compreſſure, at leaſt on their ſurface, which conſiſts of a ſoft yielding glue. Such particles then having the ſame power of mutual tendency or attraction, will each of them apart be ſpherical; but when two or more of them meet in contact, their ſurfaces muſt yield in proportion to the denſity and vicinity of their central contents, and from round, become depreſſed ſpheroids or cakes, whence both their contacts and coheſion will increaſe, yet ſo as to allow a free motion of the central parts to ſlide one by the other ſo long as the quantity and tenacity of the ſurrounding glue anſwers to the moving diſtractile force applied. A number of ſuch parts then united longitudinally will form a ſimple, elaſtic and diſtractile fibril; or ſix of them conjoined together, at equal diſtances, will form a ſimple, elaſtic and leaſt globule: and thoſe we ſee make the primary and moſt ſimple inſtruments of motion in an animal body, to the ſtate or diſpoſition of which all the other ſolid or fluid parts they compoſe correſpond in the ſtrength and action. Here the ſolids, as the main ſpring, have the predominant ruling force over their elaſtic contained fluids, which, as the regulating or weaker ſpring muſt anſwer in their nature and motion to the former; whence the diverſity of native conſtitutions.——If the central points of theſe earthy ſtamina, in a fibre or globule, come cloſe enough to cauſe a due coheſion of parts, which may ſufficiently yield to and return the given impulſe required, 'tis ſaid to be healthy and *robuſt*. If their coheſion be too cloſe, and connecting glue too tough or dry, they are ſaid to be *rigid* and unactive; but if they recede farther, have a glue too watry, and cohere leſs than ſuffices to receive and return the due vibrations, they are then ſaid to be weak and *lax*. And theſe two laſt are the morbid conditions which call for the care of the phyſician. What has been ſaid of theſe primary ſimple machinulæ is true in a greater degree of the more compound membranes, veſſels and viſcera which they compoſe; and alſo of the lymphatic, ſerous and red ſpherules, with reſpect to their conſtituent parts, and to each other.

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* Theſe are the common phyſical or natural elements of all animals and vegetables, eaſily commutable one into the other.

Hence we ſee, (1) that *life* is the mere motion, and *health* a certain latitude or degree of that motion, betwixt the elaſtic ſolids and fluids, extended through a ſeries of vaſcular parts gradually more compounded. (2.) That an exceſs or defect in this motion alters the texture towards death or diſeaſe. (3.) That moderate exerciſe repeated makes the parts ſtrong and healthy, by keeping them moveable upon each other, by expelling the redundant watry parts, and giving the whole glue a due firmneſs and coheſion. (4.) That one of the leaſt veſſels cloſed into a fibre muſt be ſtronger than that veſſel was before? from the increaſed contact and coheſion. (5.) That a callus is tougher and leſs diſtractile than original fleſh? becauſe it is leſs vaſcular and without the interpoſition of cellular ſubſtance; whence alſo it will be little or nothing perſpirable. (6.) That the ſtrength, rigidity or laxity of the fluids and ſolids are correſpondent one to the other; i. e. lax ſolids will make lax thin fluids, whence a weaker reaction of them in the veſſels, &c. which will pave the way to ſlow, cold diſeaſes; as the contrary will diſpoſe to acute inflammatory diſeaſes. (7.) That aſtringents are ſuch as approximate the ſolid ſtamina and thicken their connecting glue; whence they ſtop evacuations by thickening the humours and leſſening the diameters of the veſſels: ſo that given ſparingly in laxity of the ſolids and fluids they corroborate; but in exceſs, and in old, laborious rigid ſubjects, with an inflammatory lentor, (or even in a cold viſcidity, unleſs joined with ſtimulants) they coagulate the juices and ſuppreſs the actions of the ſolids. (8.) That oils relax without weakening, becauſe they have a greater tenacity than water; which laſt diſſolves the connecting glue and weakens the automatic action or elaſticity of the ſtamina and fibres thence ariſing. For which reaſon large and ſudden evacuations leaving the ſolids looſe and unactive upon the fluids, cauſe faintings and weakneſs. (9.) We ſee that where there is a natural laxity of the blood and its veſſels, as in women and children; where they move with a greater impetus than ſuits their coheſion, as in fevers and periodical hæmorrhages; or where the connecting glue is too much diſſolved by a putrid alcaline contagion, as often in eruptive and epidemical fevers, there may be an extravaſion (according to the degree or multitude of thoſe cauſes) either of ſerous or ſanguineous fluids into the cellular ſubſtance of the ſkin, and other larger internal cavities, without a rupture of veſſels, in which manner flow the courſes of women. Hence by a diſſolution of the connecting glue, from a venereal or ſcorbutic acrimony, the bones, veſſels and the elaſtic globules break eaſily; whence frequent hæmorrhages with livid cutaneous ſpots, &c. And thus hæmorrhages happen ofteneſt in the noſe and lungs, becauſe the arteries have their coats there thinner, and in the lungs have little reſiſtance or confinement from the empty cells, and very thin epithelium or internal cuticle:

whence an infection is ſooner ſent to the blood through theſe parts, and conſumptive ulcerations here oftener take place. (10.) We ſee that from the birth, the ſtrength and cohesion of the ſolids gradually increaſe with age, while the fluids continue leſs altered, till at length a ſenile weakneſs and natural death enſue from the dead reſiſtance of the rigid membranes and veſſels not yielding to the now weaker nervous influx; the nervous ſecretion daily leſſening and the cortex indurating as the veſſels cloſe by age. (11.) We ſee how an injudicious internal uſe of aſtringents powerfully contracting the larger veſſels, may rather increaſe than ſtop an hæmorrhage, and ſome local fluxes; or by cauſing too great a puſh upon the ſmaller veſſels in a weakened part, may produce one de novo. (12.) We ſee that in the warmer countries and ſeaſons of the year, where there is always a greater tenacity of the fluids and a weaker ſpring or action of the ſolids, bleeding is oftener called for to relieve the tone of the veſſels in full habits; and this eſpecially in wine countries, as ſouth of France, Spain and Italy; for that from its globular matter and moderate increaſe of the circulation breeds blood very faſt. (13.) We ſee why in moſt fevers, and in colder countries or ſeaſons, 'tis neceſſary for the patient to have a moderately warm room, warm bed, warm drinks, ſleep, &c. by which the tenſion of the veſſels is relaxed, and tenacity of the humours leſſened; from both which a fever is augmented. (14.) We ſee how a thick moiſt air in foul weather, ſeems heavy to us, though it be much lighter than a dry ſerene air? becauſe from its leſs preſſure on the body the ſpring of the ſolids upon our fluids is weakened. (15.) Why onions, muſtard, pepper and other alcaline ſtimulants are uſed to promote the digeſtion of putreſcent meats, pork, ſalt-fiſh, &c.? becauſe they are antiſeptic and by increaſing the muſcular ſtrength of the ſtomach make them ſtay there not too long. (16.) Why a dropſical patient ſo eaſily relapſes after freeing him from his waters? becauſe being lodged where the fibres have the leaſt tone and elaſticity, as in the lymphatics and cellular ſubſtance, where corroborants ſeldom penetrate, 'tis very difficult to reſtore or confirm their firſt ſtrength. (17.) What pains are increaſed and what leſſened by blood-letting? namely it relieves in full habits with a pleuritic or ſizy blood, but where rheumatic or hyſterical pains come from too great a laxity of the ſmaller veſſels and a looſe watry ſluggiſh blood, Gum. Guaic. Cinnab. Cort. Peruv. Rad. Valer. Rhei & Camph. are preferable to the lancet, as that increaſes the generating cauſe. (18.) Why inflammatory tumours are painful and reſiſting, but œdematous ones indolent and pitting? becauſe the lymphatics and cellular ſubſtance, the uſual ſeat of the laſt, have but little elaſticity and ſenſibility. §.21. (19.) Why inflammation and pain are always leſs by bleeding; and how it may provoke perſpiration, ſweat or urine? viz. by abating the compreſſure of the excretory ducts, by leſſening the force and diſtention of the blood veſſels, and by relaxing the blood and humours themſelves urging upon the diſtreſſed part. (20.) Why the pulſe of a fat perſon compared with that of a lean one is weak and languid to the touch? namely becauſe the ictus is loſt in a ſoft, unreſiſting and unelaſtic ſubſtance, and receives little or no increaſe or return from the well-cloathed contiguous bone. (21.) That ſudorifics, diuretics and ſcarifications are much preferable to tapping or ſtrong purging in dropſies; becauſe by exhauſting the parts gradually they better contract and recover their loſt tone, while the better elaſtic or globular parts of the juices are ſtill retained in the habit. (22.) That there are no proper or peculiar adipoſe veſſels and receptacles, only ſuch as are alſo common as well to the watry and gelatinous as by a greater laxity or impulſe to the ſerous and even red parts of the blood from whence the fat laterally recedes. Laſtly, as the cellular fabric ſurrounds every individual tubulus or nervous fibril, both in the encephalon, in its progreſs thence, and in its ultimate expanſion (23); we ſee thence how a weakening of this fabric, by exceſs of dram-drinking, tea-drinking and lewdneſs, has reduced the old athletic Britiſh conſtitution of our anceſtors to the modern puny tenerity of habit, obnoxious daily to a train of nervous and other diſorders, almoſt unknown to our progenitors. And why theſe have worſe effects on the young, witty, ſtudious and ſedentary; who have a natural tenderneſs of the cellular fabric and nervous ſyſtem; to relieve which, the cortex was timely and happily diſcovered.

LECTURE III.

Of the arteries and veins.

§. 26. THE compound membranes made out of the preceding more ſimple parts, we ſhall hereafter better deſcribe each in their reſpective places. Of theſe membranes there are ſeveral common to the arteries; which are elaſtic tubes or canals, forming parts of longly extended cones, whoſe diameters decreaſe as they divide into more numerous branches. But where the arteries run for ſome length, without ſending of branches, as towards their ultimate extremities, their convergency is not very evident; and at length, where they are called capillaries, and wherever they give paſſage to only a ſingle red globule, they are either cylindrical or very nearly ſo, from the imperceptile diminution; but their tranſverſe ſections are every where and without exception circular, when the artery is full. The common baſis of the cone in all arteries is either in one or the other ventricle of the heart; and the apex of the cone terminates either in the beginning of the veins, or in the beginning of the cylindrical or anaſtomoſing part of the artery. In ſome places indeed the arteries ſeem to diverge or dilate; at leaſt they become there of a larger diameter after they have been filled or diſtended with wax; which poſſibly may ariſe from ſome ſtoppage of the wax, by whoſe impulſe that part of the length of the artery becomes more diſtended than the reſt. Examples of this kind we have in the vertebral artery, at the baſis of the ſkull, in the ſplenic artery, in the flexure of the carotid artery, according to Mr. Cowper's injections; and laſtly, unleſs all my experiments deceive me, in the ſpermatic arteries.

§. 27. There is indeed *no external adventitious coat* perpetual and proper to all the arteries; but the office of ſuch a coat is ſupplied to ſome of them by one ſingle external and incumbent integument, which in the thorax is the pleura, and in the abdomen the peritonæum. In the neck a ſort of thicker cellular-ſubſtance ſurrounds the arteries; for the membrane of the pericardium which on all ſides cloſes round the aorta, ſoon diſappears by changing into the cellular ſubſtance. The dura mater imparts a capſule that ſurrounds the carotid artery as it paſſes out thro' the hole in the ſkull for that purpoſe. But the firſt true external membrane common to the arterial tube in all parts of the body, is the cellular ſubſtance (§. 17.) which in ſome parts, (as in the thorax) we often ſee repleniſhed with fat. (§. 19.)

§. 28. This *cellular coat* is in its external ſurface of a *more lax*, open texture, painted with a great many ſmall arteries and veins; and it has nerves running through its ſubſtance, which are none of the ſmalleſt.

There is ſometimes ſo much of this cellular ſubſtance about the artery as might occaſion one to think it hardly belonged to it as an external coat or lamella, but rather as ſome foreign net-work added to this veſſel. Thus we find it in the arteries of the neck, groins and ſubclavians; in the meſenteric, cœliac and hepatic arteries. And theſe are the vaginæ or capſules of the arteries, formerly obſerved by ſome eminent anatomiſts.

§. 29. As this *cellular coat* advances more inward, and nearer to the light and capacity of the artery, it becomes *more denſe* or ſolid, and is tied more cloſely together by ſmall fibres, inſomuch that there appears to be no tendinous coat of the arteries diſtinct from this laſt part of the cellular ſubſtance; as is evident from maceration, whereby the inner ſtratum of this arterious tunic changes into a cellular fabric.

§. 30. Within the former, and nearer the light or capacity of the artery, it has *a coat of muſcular fibres*, which are in general imperfect circles; that is to ſay, no fibre any where makes a compleat circle round the veſſel, but a number of ſegments conjoined together, with their extremities turned off ſideways, ſeem to form one ring round the artery. Theſe fibres, in the larger arterial trunks, form many ſtrata or plates one within the other, appear of a rediſh colour and are remarkably firm and ſolid; but in the ſmaller arteries they are by degrees more difficult to demonſtrate. Within this there ſeems to be a ſort of continuation from the former cellular membrane from betwixt the muſcular fibres, although it be among them inviſible, and here very difficult to demonſtrate; into the cells of which a chalky concreting matter is poured when an artery oſſifies.

§. 31. The *innermoſt coat* of the artery is thin or cuticular, and finely poliſhed by the influent blood; ſo as to form a ſingle incruſtation that every where lines the fleſhy fibres, (§. 30.) which being ſomewhat looſe, or not very continuous one to the other; this innermoſt lining prevents the blood from inſinuating into the ſpaces betwixt them. 'Tis every where ſmooth and without valves, altho' from a ſort of mechanical neceſſity it ſometimes, at the origination of branches, forms a projecting eminence; as we ſee at the branches produced by the arch of the aorta. Yet in arteries of the viſcera the innermoſt coat is ſofter and more lax than what we have deſcribed; and 'tis there in a manner wrinkled and almoſt friable.

§. 32. The arteries themſelves *have arteries* which are more particularly ſpread thro' their external cellular coat; and ſpringing on all ſides from the next adjacent ſmall arterial trunks, form numerous, branchy net-works, which are all of them indeed very minute, but plainly appear, even in the fœtus without injection, to be very numerous. We ſee alſo there are *nerves* which deſcend for a long way together through the ſurface of the artery, and, at laſt, vaniſh in the cellular ſubſtance of the veſſel; of which we have a ſpecimen in the ex and internal carotids, and arch of the aorta. And from theſe, as in other muſcles, the arteries ſeem to derive a muſcular and convulſive force*, very different from that of their ſimple elaſticity. Does not this force ſhow itſelf plainly enough in fevers, faintings and paſſions of the mind? But the artery, abſtracted from its nerves, is in a manner inſenſible and unirritable.

REMARK.

* This is a ſucceſſive contraction of the arterial fibres, like thoſe of the inteſtines, from the larger to the leſs diameter, or the reverſe; by the firſt, the blood moves quicker in a certain trunk to the veins, as in bluſhing, anger, &c. by the laſt, it reverts back to the heart in faintings, hyſterical fits, &c. Hence come the pains, improperly called flatulent, which are local cramps of the artery, beyond which you will ſcarce feel any pulſe, but before it a ſtrong one; whence, in hyſteric, and other nervous caſes, you have often a pulſe in one wriſt and little or none in the other. When violent in the carotids, it often kills by an apoplexy, that is now a-days very frequent, and in which bleeding avails little. Seizing the heart itſelf, it often kills ſuddenly, without leaving any apparent cauſe, upon diſſection. (V. Williſii Cap. 8. de apoplexiâ obſ. ult. in Theologo). By this periſtaltic motion

of the arteries, the paſſions quicken, retard or ſuppreſs the renal, uterine, hepatic, lactiferous, ſalival, and other ſecretions; being a great key to many otherwiſe unintelligible ſymptoms, &c. See §. 44 and 553.

§. 33. The *ſections* or diviſions of arteries ſhow themſelves with a round, light or hollow capacity, becauſe they are elaſtic; and this is the reaſon why, from ſmall arteries, as thoſe of the teeth, hæmorrhages are ſometimes fatal. The aorta, indeed, of the thorax and abdomen, the carotids of the neck, and ſome other arteries of the dead body, from their leſſened extenſion, appear ſomewhat flat or depreſſed; but their round figure or circular ſection is every where reſtored by injection. *Their elaſticity* is alſo evident in that powerful compreſſure, which a ſegment of a large artery makes upon the finger that diſtends it. In the living body, indeed, this force yields to that of the heart, but inſtantly recovers itſelf, when the heart is relaxed, and reſtores the artery to its former diameter; and this makes the pulſe, whoſe full explication ought to be preceded by an hiſtory of the heart: at preſent, it may ſuffice for us to ſay, that all the arteries have this pulſation, although the ſyſtole and diſtole thereof can be perceived by the finger, only in the larger ones, and not in the ſmaller ones naturally; but by an increaſed motion of the blood even the leſſer ones make a violent pulſation, as we ſee in an inflammation.

§. 34.

§. 34. The *ſtrength* of the arteries is conſiderable enough, but as the denſe, hard network of the outer cellular coat (§. 29.) refuſes to yield to a diſtending force, it breaks without much difficulty, almoſt eaſier than the coats of the veins; and from thence aneuriſms often ariſe. But in general, the trunks are, in all parts of the body, weaker, and the branches ſtronger in their coats; whence the impulſe of the blood may exert a conſiderable effect upon the former, but leaſt of all on thoſe of the limbs. From hence it is, that aneuriſms are moſt frequently formed near the heart; for in the lower extremities, the ſtrength of the arteries, and of the veins too, is much increaſed.

§. 35. With regard to the *courſe and general diſtribution* of the arteries, nature has every where diſpoſed of them in places of the utmoſt ſafety, becauſe wounds cannot happen to the ſmaller of them without danger, nor to the larger without loſs of life. The ſkin is ſpread with numerous ſhort and ſmall arterial trunks, but the larger ones, defended by the ſkin, creep along betwixt the muſcles and the bones well guarded.

§. 36. In the *particular diviſion or ramification* of an arterial trunk, each branch ſends out ſmaller circles by a numerous ſubdiviſion; the laſt extremities of which, you will ſcarce be able to trace. Here the lights or ſections of any two branches taken together, always exceed the light of the trunk

from

from whence they come, in nearly a ſeſquialteral proportion, or as one and a half to one, or ſomewhat leſs. Alſo every trunk, juſt above its bifurkation or diviſion, is ſomewhat broader or more expanded. The angles, at which the branches go out from their trunks, are generally acute, either half right angles or nearly ſo; to the forming of which angles, as we ſee in mechanics, there is required the longeſt projection. Inſtances of their going off at right angles, or nearly ſo, we have in the lumbal or intercoſtal arteries; of their going off in a retrogade or reflected courſe, we have one inſtance in the coronaries of the heart, and another inſtance in the ſpinal arteries, which are produced by the vertebrals. But generally ſpeaking, thoſe, which are eſteemed retrograde or reflexed, were ſent off, at their origin, in acute angles; ſuch as the aſcending artery of the pharynx, the deſcending one of the palate, the umbilical and mammary arteries. Laſtly, we often obſerve larger arteries ariſing under leſſer angles, and ſmaller arteries under greater angles: but it is rarely, that we obſerve two arteries of a larger diameter run together into one trunk of a leſs; as in the baſilaris, formed out of the vertebral arteries. §. 338. [In many parts the arteries have repeated alternate undulations or flexures, as they run on in a ſpiral courſe, wherein we ſee their diameter often conſiderably enlarge; as in the colon, rectum, womb, face, ſpleen, &c.

This, and the diviſion into branches larger than the trunk, greatly abates the velocity of the blood; as does the largeneſs of the angle with the trunk, and the number of undulations by which an artery, that lies in a ſmall compaſs, may be eaſily extended to a great length, as in the uterus, &c.]

§. 37. The arteries are frequently conjoined one to another by intermediate or *anaſtomoſing branches*, in ſuch a manner, that the twig of ſome certain artery ſhall run to meet one of the ſame kind from another neighbouring artery, and by joining together with that form one trunk. Inſtances of this kind we have many, among the large trunks in the inteſtines; among the middling ones, in the kidneys, womb, &c. and among the ſmaller, in all parts of the body; inſomuch that there is no one part of the human body, wherein the neighbouring arterial trunks, whether of the ſame, or of different denominations, do not form anaſtomoſes or joinings one to the other, by intermediate, lateral branches. Of ſuch rings diverging laterally from the arteries, and returning again into themſelves, we have inſtances betwixt the iris and choroides of the eye. The extremities of the arteries, which are either cylindrical or nearly ſo, ſend off ſmaller branches, which, for their extent, are more numerous, and generally diſpoſed like a net, ſo that each branch, by ſmaller circles, forms anaſtomoſes with thoſe of its neighbouring branches. And thus we find it in all membranes.

§. 38. Laſtly, one of the leaſt arteries is either changed by a continuation of its canal into a vein, in ſuch a manner, that the ultimate little artery, which is generally reflected, having ſurpaſſed the angle of its reflection, becomes now a ſmall incipient vein; or elſe, a branch, ſent out at right angles from the artery, is inſerted under a like angle into the branch of a ſmall vein. Both theſe kinds of mechanical fabricature of the ſmaller arteries with the veins are demonſtrated to us by the microſcope. And theſe vaſcules we ſee ſometimes large enough to receive only one, and ſometimes ſeveral blood-globules at a time. See §. 69. *In the viſcera*, we find the ſmall arteries diſpoſed not ſo much in net-works, as in a different fabricature, wherein the ſmall branches deſcend very thick or in cluſters, parallel to the trunk, ſo as to reſemble bruſh-pencils, a variety of little trees or buſhes, ſmall ſerpents, threads, &c. according to the variety of the parts, whoſe compoſition they enter.

§. 39. Other arteries again paſs not into veins, but *into excretory ducts*, like unto veins, which convey a humour different from that of the blood. This continuation of the arteries and ducts is ſomewhat more difficult to diſcover than the former, (§. 38.) and is generally not ſo eaſily deſcribed or traced by the injection or liquor that is urged into them.

§. 40. Another termination of the arteries is, *by branching out into pellucid ones*, of much leſs orders, which we ſometimes obſerve to be not only continuous, but true and direct trunks of the ſanguineous arteries; as in the ophthalmic artery of the eye, if you trace its branches into the choroides, then into the arterial circle of the uvea, and laſtly, into the colourleſs arteries of the iris, vitreous body, and cryſtalline lens: ſo likewiſe, in the red branches of the ſame ophthalmic artery forming a net-work in the conjunctiva tunica, to which is continued the pellucid, but arterial net-work of the albuginea or ſclerotica: the truth of this appears from inflammations, from the redneſs of parts cauſed by warm vapours, from cupping, from artificial emptying and repletion of the arteries, and laſtly, to the eye itſelf by the microſcope of Lieberkuhn, commonly called ſolar, applied to the membranes of frogs, by which we ſee the colourleſs globules paſs out of a red artery, and go off into pellucid continuous ones. The uriniferous ducts or tubes of the kidney are thus continuous with the ſanguine arteries. In this ſtructure of the arterial extremities, we ſee it is no difficult matter to urge any red liquor or coloured injection into the ſmaller pellucid veſſels.

§. 41. As for the ſmall, lateral, excretory ducts, we before mentioned, (§. 39.) which ſeem to go off as branches from the ſmalleſt red arteries, and again laterally detach other trunks; they make a greater reſiſtance, than the former, to an injection; whence it becomes more difficult to fill their excretory veſſels. And this ſeems to be the fabric in moſt of the ſmall glands and viſcera, deſtined for ſecretions; where, with ſome difficulty, we can urge a liquor from the arteries into their excretory ducts.

§. 42. Another termination of the arterial extremities, is, *into the exhaling veſſels*; and this is a manner of their ending, very frequently to be obſerved in all parts of the body. The whole external and internal ſkin, all membranes of the human body, which form any cloſe cavity, all the ventricles of the brain, the anterior and poſterior chambers of the eyes, all the adipoſe cells and pulmonary veſicles, the whole cavity of the noſtrils, phauces, ſtomach and inteſtinal tube, through which the air has a paſſage, are all of them repleniſhed with exhaling arteries of this kind. Theſe breathe out a thin, watry vapour or humour, very little gelatinous, which being condenſed or collected together by ſtanding, ſometimes makes no inconſiderable quantity; and particularly, by diſeaſe or death, they yield a watry, but congealable lymph, hardening by heat or alcohol. The truth of this is eaſily demonſtrable, from the watry ſweat that enſues after injecting the arteries with that liquor warm. In ſome places, indeed, they exhale not a thin vapour, but blood itſelf, as we ſee in the cellular fabric of the penis, urethra, clitoris, and nipple of the female breaſt; in all which, the blood itſelf is naturally poured out. Does not every ſecretion, that is made in true glands or hollow cryptæ, bear ſome analogy to this exhaling fabric?

REMARK.

Even the whole encephalon and nervous ſyſtem are a kind of cylindric, exhaling veſſels, whoſe contents are, in part, elaſtic globules, and move the ſloweſt of any juice; in ſome nerves, by tubular attraction and arterial impulſe, only modulated by impulſions of objects one way, and (in ſome) of the mind the other way: this juice, moving in the organ immediately by continuity, moves the mind, as the mind again thereby moves the organ, not by any flux, but by a transfered motion; as when 10,000 ivory balls fill a tube, if you put in one more it will inſtantly thruſt out another at the oppoſite end.

§. 43. Whether or no, in all parts of the human body, the pellucid veſſels, (§. 40.) ariſing from the ſanguine ones, and carrying a humour thinner than blood, again ſend out other ſmaller veſſels to be ſubdivided into ſtill leſſer orders? We ſeem, indeed, not to want examples of this, in the manner propoſed.

poſed to us by the celebrated Boerhaave and other profeſſors. That the aqueous humour is ſeparated by very fine veſſels, generated from the colourleſs arteries of the iris, is, indeed, more than probable. That the red coloured veſſels, in the cortical ſubſtance of the encephalon, ſeparate a juice, pervading the medullary ſubſtance, by the intermediation of other ſmaller veſſels, we are almoſt certain. And the like we are perſuaded from an eryſipelas, or yellow inflammation, ariſing from the yellow or ſerous globules, impacted into ſmaller veſſels.

§. 44. It may be then aſked, if there are not yellow arterious veſſels of a ſecond order, which ſend off lymphatic ones of a third order, from whence, by degrees, ſtill leſſer kinds of veſſels branch out? ſuch a fabric does not ſeem agreeable to the very eaſy tranſition that is made by the blood, mercury or wax into the exhaling and perſpiratory veſſels; into the uriniferous tubuli, with the adipoſe and pulmonary cells; nor is it very difficult for the blood to ſtray into the lactiferous, lymphatic and lachrymal ducts, whither it ſhould ſeem not able to penetrate, if it went through any other intermediate vaſcular ſyſtem, ſmaller than the blood-globules, which make the ſame journey. Nor can this ſyſtem be allowed by the great impediment or retardation that muſt ariſe to the humours in a third, and much more in a fourth, and leſſer orders of veſſels.

REMARK.

From what has been ſaid, we ſee the arteries act by a double force on their contents; the one, a dead automatic elaſticity, (32.) the other, a vital or muſcular conſtriction from the nerves in their fabric. (33.) The firſt continues to operate in the dead animal, the latter only in the living; and that variouſly, as to force and celerity in different organs, or in one and the ſame organ at different times, in proportion as their nervous fabric is more or leſs irritated by diſtention or acrimony internally, or from pain, paſſions or nervous conſent externally. This is the force that gives a due form and modulation to many of the ſecerned juices, and carries them through ducts and veſſels, which, after death, are no longer pervious; and, although the great ſhare which it has in almoſt all febrile or inflammatory, nervous and painful diſeaſes, ſeems little regarded by our Britiſh phyſicians; yet, ſome of the greateſt note, and particularly among the Germans, have built their ſyſtems almoſt entirely hereupon: thus, ſometimes Hippocrates calls it nature, Helmont calls it his archeus, Hoffman and Sthall their convulſive ſpaſms; ſo prolific of diſeaſes.——Theſe are the forces which actuate all medicines ſo as to produce their various effects, which are always in proportion to the ſtate of theſe powers and that of the confined juices on which they act; and, therefore, never exactly the ſame in two people, or at two different times.—— Theſe powers, however, in ſome meaſure, antagonize one the other; for the greater the arterial denſity, the leſs their nervous irritability and the reverſe. The former, too much increaſed, paves the way to all acute, inflammatory and painful diſeaſes; as the latter does to all ſlow, nervous and hyſterical complaints. This laſt is the door-keeper to the catamenia, whoſe generating or material cauſe is a plethora, but the motive or actual cauſe a fever, with a topical or painful irritation of this ſluice-keeper in the womb, without whoſe permiſſion, a plethora can never iſſue there. This is the milk-maker in the breaſts, to which the chyle affords matter to be moulded: milk and chyle being very diſtinct humours, &c. we ſee the nervous ſyſtem influences this muſcular power of the arterial; and that again acts upon the nervous, both as to the ſecretions and diſtributions. All pleaſing paſſions and ſenſations, as well as painful, uneaſy ones, variouſly intend or remit the circulation, by acting on this muſcular fabric and force of the heart and arteries. All medicines in themſelves are dead tools, which exert effects varying according to the ſtrength or diſpoſition of this agent, viz. the elaſtic and muſcular force of the artery, in conjunction with the denſity or laxity of the humours, and more or leſs ſenſibility of the nerves. A ſpaſm of this muſcular force of the artery in any emunctory, cauſes a ſuppreſſion, as in the ſkin, kidneys, lungs, womb, &c. to be relieved by warm bathing, vapours, ſemicupium, opiates, nervous and hyſterical medicines, after one ſpare bleeding. Any ſlow ſtimulus acting on this nervous and muſcular force of the arteries, cauſes a nervous atrophe, whether from pain, want of mucus, putrid or ſcorbutic acrimony, &c. In a word, this is a principal key towards underſtanding the nature and cure of numerous ſymptoms of diſeaſes, and the various operations of medicines. See §. 552 and 553.

Of the veins.

§. 45. The *veins*, in many particulars, (§. 36.) reſemble the arteries. Their baſis is in the ventricles of the heart, and their apices in the extremity of each branch, thro' all parts of the body, excepting one inſtance in the liver. And, in a great number of parts, they run parallel with the arteries, one by the ſide of the other. But the veins differ from the arteries in various reſpects, as we ſhall now ſee.

§. 46. The membranous fabric of the veins is thin, every where ſmooth, and very difficultly ſeparable into diſtinct coats or membranes, in which there are but few places, wherein one can demonſtrate muſcular fibres. Notwithſtanding this thinneſs of their ſides, the veins are, in moſt parts, very firm, and do not eaſily burſt with inflated air; being, in moſt inſtances, ſtronger than the arteries, if experiments do not deceive us. But they burſt much more eaſily in living, than in dead animals, as appears from morbid inſtances in the arm, face, leg, thigh, &c. Nor do they ſupport themſelves like cylinders after being divided, but they collapſe together, ſo as to make their light or capacity appear like a ſlit; except they are ſuſtained and hindered from collapſing thus, by ſome ſtronger cellular ſubſtance placed round them, as we ſee in the liver and womb. [They are like the arteries, but ſlightly irritable, unleſs the ſtimulus be of the chemical or more acrid claſſes; for, in that caſe, they contract themſelves with a convulſive force, greater in proportion than that of the arteries themſelves.] (§. 32.) They have no pulſation, unleſs the venal channel is ſomewhere obſtructed; or when, in dying people, the blood is thrown back again from the right auricle into the deſcending and aſcending cava.

§. 47. The veins are much larger than their correſponding arteries, having the ſquare of their diameter often double or triple that of the latter, and, in ſome places, almoſt quadruple; as near the emulgents, and in the venal trunks. They differ, likewiſe, from the arteries in their courſe or diviſion; having more numerous trunks and branches: for to one artery in the limbs, we uſually meet with two veins. The larger veins are alſo branched in a more net-like diſpoſition, by forming more frequent anaſtomoſes one with another; for not only the ſmaller branches, but even the larger trunks of the veins are conjoined one to the other within its neighbourhood, upper with lower, and right with left, by apparent inlets or inoſculations. They affect more than arteries to run near the ſurface of the body; and through the limbs, neck, head, &c. they run a long way covered with little more than the bare ſkin; which is a circumſtance we very rarely obſerve in arteries: and for the ſame reaſon, they often go out in their courſe, to a conſiderable diſtance from the arteries. For, in this caſe, the veins follow the ſurface of the parts next the ſkin, without their correſponding artery, which, in the mean time, deſcends to a conſiderable depth, attended, in its courſe, by ſome ſmaller venal branch. In the ſmaller branches of the veſſels, where they make net-like diſpoſitions in the membranes, and compoſe the internal fabric of the viſcera, the veins and arteries commonly run contiguous one with the other; but here the veins have generally a leſs ſerpentine or inflected courſe.

§. 48. The veins have their origin, as we ſaid before, (§. 37.) from the terminations of the arteries. They ſometimes ariſe by a continuation from the inſerted branches, or from a reflexion of recurved trunks, of the ſmalleſt arteries. Others again are either continued from veins leſs than thoſe which carry blood, or elſe receive additions and roots from them; as we ſee, for inſtance, in the lymphatic veins of the thoracic duct. Other veins, of a bibulous kind, ariſe from abſorbing ducts or orifices opening throughout the whole extended ſurface of the body; as in the chambers of the eyes, the cavities of the inteſtines, bladder, womb, breaſt, peritonæum, pericardium, and ventricles of the brain. For from theſe iſſue a watry ſweat, by injecting the venal trunks with that kind of liquor, which eaſily reſembles an ordinary ſweat throughout the whole human body: hence, we meet with injections of water, fiſh-glue or oil diſtilling from the vena portarum into the cavity of the inteſtines; of which experiments, we ſhall ſpeak more largely hereafter in a proper place.

§. 49. Not much differing from the former, are thoſe veins which, ariſing in all parts of the cellular membrane, or rather ſponge-like ſubſtance, return thin vapours, dropſical waters, and diſſolved fat again into the maſs of blood; or which take up again and return the blood itſelf from the cellular fabric of the penis, clitoris, or nipples of the breaſts after the venereal act. And that inhaling veins of this kind open into all the glands, is highly probable; where, by abſorbing the thinner humour, they leave the remaining maſs of a thicker conſiſtence; of which we have inſtances in the bile, ſperm, mucus, &c.

§. 50. That there are pellucid veins of a ſmaller claſs, but reſembling thoſe which convey blood, appears from the ſame experiments, which demonſtrate the pellucid arteries (§. 40.): thus in the iris of the eye, there are ſmall veins, and in the adnata tunica of that organ, more than a few trunks, which, in a healthy perſon, are naturally pellucid. The larger of theſe veins, which come next to thoſe that carry blood, are much more conſpicuous than the arteries of the ſame kind; and are uſually called *lymphatic veſſels*; of which we ſhall ſpeak more at large, when we come to deſcribe the *lacteal veſſels*.

§. 51. Namely, in moſt parts of the human body [but in brute animals they are more eaſily and clearly diſcovered] are found tranſparent veins, often full of a reddiſh, yellowiſh, and almoſt pellucid liquor, hardening like the white of an egg with a boiling heat or alcohol; which veins being formed of very thin coats, [have, like the blood-veins, (§. 46.) a proportionable degree of irritability, from any chemical or very acrid ſtimulus; whence we infer them to be muſcular or nervous, notwithſtanding they are pellucid, like the fibres of fiſh, frogs, &c.] have frequent valves or partitions, which make them in thoſe places ſeem jointed, or knotted like a reed, when they are turgid; theſe, by degrees, meeting together, either all or moſt part of them, empty their contents into the thoracic duct. But all the lymphatics, in their courſe, meet together in a peculiar kind of conglobate glands, into which they enter, and from the ſhape of veins becoming arterial or like converging cones, they divide into ſmall branches, and then proceed to meet together again in other little trunks. They are found ſeated on all the ſurfaces of the viſcera, in the thorax and abdomen; but are more eaſily and clearly diſcovered in brutes: they run thro' the lower part of the face, muſcles of the tongue, the adjacent parts of the neck, and thoſe parts of the upper limbs, which are neareſt the trunk, as far as the bending of the elbow; throughout the whole length of the mediaſtinum, before and behind, and wherever we find conglobate glandules, either in the neck or thorax: the lymphatic veins are alſo ſpread through the whole lumbal region that is contiguous to the aorta, the meſocolon and pelvis, veſſels and ſurface of the teſticle; and in the lower limbs wherever they are ſupplied with conglobate glandules. Whether they extend further into other parts, throughout the whole body, or through the brain, eyes, hands, feet, back, fore part of the peritonæum, &c. remain, as yet, undetermined; at leaſt, there are not examples enough in the human body, upon which one can depend to evince the truth of their exiſtence. But they are every where to be found upon the ſurfaces of the viſcera, and about the larger blood veſſels.

§. 51. The *valves* of theſe pellucid veſſels are compoſed of two ſemilunar, or rather ſemicircular, projecting membranes, which give way to the fluid that goes towards the larger trunks; ſo that, by applying themſelves cloſe to the ſides of the veſſel, they leave a free light or capacity thro' it. But the ſame valves, if the contained liquor is preſſed back towards the ſmaller branches of the veſſel, being filled out therewith, ſwell or expand, ſo as to ſhut up the light of the canal.

§. 53. But many valves of the ſame kind are alſo found in great numbers *within the* larger *blood-veins.* Theſe, joined with the ſide of the proceeding vein, intercept a ſpace, of which the outerſide is the vein itſelf, and the inner the valve, which, by its convexity, ſtands out within the bore or light of the vein; ſo that the parabolic ſpace or hollow mouth of the valves always look towards the heart: they are found in all the ſubcutaneous veins of the limbs, in thoſe of the neck, face, tongue, and in the veins of the penis: at the origin of the larger branches there are two, three, four, and ſometimes five of them together, while in their ſmaller branches they are only ſingle. There are none of theſe valves in the deep running veins of the viſcera; and, therefore, none in thoſe of the brain, lungs, heart or liver, or through the whole ſyſtem of the vena portarum, nor in the kidneys or womb (except one or two valves in the ſpermatic vein); nor, laſtly, are there any in thoſe ſmaller blood-veins, which are of a leſs diameter than the twelfth part of an inch. Whether there are any ſuch valves in the vena azygos is queſtioned; but I have not been able to find any. [Valves have been ſometimes, though very rarely, found in the vena azygos: and at the mouths of the hepatic and renal veins: there I have ſeveral times obſerved a ſort of wrinkles in the place of valves.

§. 54. In the ſmaller venal branches there are a ſet of long, ſharp-pointed or parabolical valves of a more extended figure, as the vein is ſmaller: and theſe make a greater reſiſtance than the larger valves, to hinder the blood from returning back upon the parts.

§. 55. The common uſe or office of theſe valves is, to determine the preſſure that is given from any quarter upon the veins, towards the heart, by allowing no opportunity to the venal blood, that has once entered the trunk, which they intercept, to flow back to the branches. For ſince the coving ſpaces of the valves open upwards towards the heart, the blood enters into, and expands them. Thus thoſe parts of the valves, which ſtand out with a free motion within the light of the vein, approach each other towards the axis, until the oppoſite ſides, by meeting together, ſhut up the tube. This we know from inflations, ligatures and injections of the veins; for you never can force a liquor eaſily into the veins, by urging it againſt, or contrary to, their valves. They do not, indeed, every where ſhut up the whole cavity of the veins; but where they ſhut not cloſe, they always intercept the greateſt part of the light.

§. 56. Another office of the valves in the veins, ſeems to be for ſuſtaining the weight of the blood, that its upper columns may not gravitate upon the lower; nor the blood, flowing through the trunks, make too great a reſiſtance againſt that which follows it through the branches. For if, from the ſlower return of the blood into the veins, its weight or preſſure ſhall, in any part, much exceed the impulſe, that drives it on, ſo as to cauſe ſome part of the column to deſcend by its weight; 'tis, in that caſe, immediately catched and ſuſtained in its relapſe by the next adjacent valve, which hinders it from urging againſt the next ſucceeding column, and affords time and opportunity for ſome contiguous muſcle, by its preſſure or concuſſion, to ſend forward the ſaid column. And this is the reaſon, why valves are placed in veins of the limbs and neck; in which parts, they are both more numerous and more robuſt than elſewhere. And this is the cauſe, from whence varices or herniæ are formed in the veins, when the blood, entering the hollow valves, urges their ſolid convexity downwards, and makes the vein dilate in that part.

LECTURE IV.

Of the circulation or motion of the blood through the arteries and veins.

§. 57. THE arteries and veins, which we have hitherto deſcribed, contain either blood or lymph. The red blood, whoſe nature we ſhall explain when we come to treat of ſecretion, fills the arteries and veins by all ſeen, or commonly known, which we call thoſe of the firſt or larger order, and which have their origin in the heart. Theſe the blood ſo fills in a living perſon, that, at ſome times, they are very looſely and imperfectly diſtended by it, and, at other times, they are rendered very full and turgid. After death, the veins are found fuller of blood than the arteries; but ſometimes, when the perſon has been dead a conſiderable time, the ſmall veins have been found diſtended with air. But the arteries of a dead body commonly contain only a ſmall quantity of blood.

§. 58. This diſtending blood then, in a living perſon, is rapidly moved through all the ſaid veſſels. The truth of which is demonſtrated to us from wounds, by which the patient ſoon expires, from the loſs of ſo much blood, as was neceſſary to diſtend and move the veſſels for the maintainance of life; which loſs of blood happens almoſt inſtantly from the larger arteries, and ſometimes very ſuddenly from the ſmaller ones: (ſee §. 60.) but from the veins, unleſs they are ſome of the largeſt, this loſs of blood is more ſlow and difficult; yet, are there not wanting inſtances of fatal hæmorrhages from wounds of the veins, not large as in the inner corners of the eyes, under the tongue, &c. In ſhort, the experiments made upon living animals, ſufficiently evidence the impulſe and rapidity with which the blood is moved, particularly through the arteries; where, in the larger trunks, it runs moſt ſwiftly, at the rate of 149 to 74 feet in a ſecond; but, in the leaſt of them, it runs above twenty times ſlower. And, in the larger veins, where it moves ſo much faſter than in the ſmaller, the blood's celerity is leſs than in the arterial trunks, in the ſame proportion, as the lights or ſections of the arteries are leſs than thoſe of the veins, i. e. twice or almoſt thrice ſlower. Another argument of the circulation, is the compreſſure and relaxation of a vein, whereby the blood is promoted from one valve to another.

§. 59. This motion of the blood is in the veins uniform or equable enough; but, in the arteries, it is alternately greater when that veſſel is more dilated, and leſs when it is contracted. [This is proved by ocular inſpection in living animals.]

§. 60. That the motion the blood deſcribes, is a courſe through the ſanguineous arteries into the veins, is diſcovered from experience. For 1ſt. it is certain, that all the arteries and veins communicate or open one into the other; becauſe often, from one, and that a ſmall artery, all the blood ſhall run even until death, not only out of the wounded limb, but from the whole body. Of ſuch fatal examples, we have a number from an inner artery of the noſe, from the gums, a finger, tooth, cutaneous pore enlarged, from the lachrymal point, from the wound of cupping on the ſkin, and even the bite of a leach. There are, therefore, of courſe open ways by which the blood ſpeedily flows from the venal, into the arterial ſyſtem, and the reverſe.

§. 61. That the blood again in the arteries flows from the heart towards the extreme parts of the body, is proved by a ligature in the living animal. For whatever artery ſhall be ſtopped by a ligature, a ſwelling enſues in that part betwixt the heart and the ligature, whilſt the other part is emptied beyond the ligature, which is the part of the artery more remote from the heart; neither has it there any pulſation, nor if it be there wounded, will it yield any blood. The ſame effects which we ſee follow from a ligature, are likewiſe often produced by diſeaſe; as when ſome tumor, by compreſſure, or ſome aneuriſm intercepts the motion from the heart. Inſtances of this kind we have ſeen in moſt of the conſiderable arteries.

§. 62. But for the courſe or motion of the venal blood, it has been always more doubted of; almoſt all the ancients have been perſuaded, that the blood in the veins flowed through them, either from the heart, or from the liver, to all parts of the body. Very few of them have known, that this was an error. Several of them have, indeed, acknowledged it to be falſe in the pulmonary vein: (§. 107. ult.) as Servetus, Columbus, Valverdus, Johannes Langius, Lambergius, Pigafetta, Arantius, H. Conringius Mercatus, Platerus, Spigelius and C. Hoffmannus, from whom we muſt not except Galen himſelf. But that the blood did not move from the heart in the vena cava was known to ſtill fewer anatomiſts of the ancients; perhaps, only to Andreas, Cæſalpinus, and from an extraordinary accident to Veſalius, and doubtfully to H. Dietericus.

§. 63. Dr. William Harvey is the firſt who experimentally aſſerted the motion of the blood, returning in the veins to the heart, in ſuch a manner as to render the whole intelligible, and leave no room to doubt of it. And firſt, *the valves of the veins* (as he obſerves) lead us to this truth; for all of them readily tranſmit wind, wax, or other injections to paſs from the extreme or remote part towards the heart; but they obſtinately reſiſt giving any paſſage to the ſaid wax or flatus, to paſs back from the heart towards the extreme parts, unleſs you burſt or break through them. The ſame courſe, which we ſee the veins give to wax, mercury or oil injected, muſt of conſequence be the ſame which, by their action, they give to the blood; ſince the colour of the refluent liquid will not make any change in its direction.

§. 64. Moreover, the valves, placed in the right ventricle *of the heart*, have ſuch a fabric, as we ſhall hereafter ſee, that they freely permit blood, flatus or wax to paſs from the venal trunks of the cava into the heart, but deny any paſſage from the heart again into the veins.

§. 65. Again *ligatures*, in a living perſon, may make the thing more evident. When the veins of the limbs are tied, either by deſign or accident, with the limb itſelf about the hams, arms, ancles or wriſts, the limb below the ligature ſwells, the veins fill and diſtend themſelves, ſo that one may eaſily open them, and they make a free diſcharge of blood: but, at the ſame time, nothing of this kind happens above the ligature, nor are any of the veins to be ſeen there but leſs conſpicuouſly. The ſame phænomenon happens when the veins are compreſſed by ſwelled and ſchirrhous glandules in the viſcera; and from polypus's the veins are often largely ſwelled, or enlarged into tumours.

§. 66. The experiments to prove this courſe of the blood, which have been made in living animals, are ſtill more accurate. From them it appears, that, by tying any vein, in a living animal, near the cava, or belonging to the pulmonary veins, that part always ſwells, which is moſt remote from the heart, all below the ligature appearing diſtended with the retained blood, while above and next the heart they are pale and flaccid. From this principle it is, that the ancients are uſed to apply ligatures to the limbs in profuſe hæmorrhages, to keep back ſome part of the blood, ſufficient to ſupport life, from returning to the heart, which would drive it into the wounded arteries. Laſtly, if the arteries are tied at the ſame time with the veins, theſe laſt remain flaccid and empty, but, upon removing the ligature from the arteries, the veins are immediately filled.

§. 67. Another proof we have in the *transfuſions* of blood, in which all the vital gore from the arteries of one animal is urged into the veins of another exhauſted of blood, whereby the heart, arteries, and empty veins of the latter become ſo turgid, and well repleniſhed, that they work the whole machine of the animal with a remarkable degree of vivacity, or even cauſe it to labour by a plethora. In like manner, medicinal *liquors*, *injected* into the veins, have exerted their operations reſpectively; proving anodyne, or inebriating in the brain, emetic in the ſtomach, purging in the inteſtines, or coagulating the blood through the whole body; which is a plain argument they paſs with their virtues firſt to the heart, and from thence ſent through the arteries to the organs, which they affect.

§. 68. But that the blood paſſes from the leaſt arteries into the leaſt veins, we are clearly taught by *anatomical injection*; where, by one arterial trunk, we eaſily fill all the arteries and veins, almoſt throughout the whole body; provided the liquor be watry or very fluxile, ſo as to paſs eaſily in the veſſels of the head, meſentery, heart and lungs.

§. 69. Laſtly, *the microſcope* has put the matter beyond all doubt in the pellucid tails, feet, meſenteries and membranous parts of animals, where we ſee, that the blood, brought to the extreme parts by the arteries, is poured either into ſmall veins, continuous with the reflexed artery, or elſe goes through branches of the arterial trunk into the parallel communicating vein, by which it goes on to the parts neareſt the heart. This is the way in which the blood paſſes as well into the leaſt veins, which are capable of receiving only one globule, as into thoſe that are ſomewhat larger, being able to admit two or more globules to advance forward in a breaſt. But that there is no ſpongy or parenchymous interpoſition betwixt the arteries and veins, in the general courſe of the circulation, is proved both from microſcopes and injections. [For if there were any ſuch parenchyma or ſpongy maſs betwixt the arteries and veins, the hardening injections would ſhow it, by appearing extravaſated in a like unſhapen maſs.]

§. 70. The Harveian circulation is, therefore, now received as a medical truth by every one; namely, that all the blood of the human body is carried through the aorta from the left cavity of the heart to the extreme parts or converging ends of the arterial branches; from whence the whole maſs is again tranſmitted into the leaſt veins, which convey it to the larger, and from them into the cava and heart itſelf; in which courſe, it perpetually goes and returns during life.

§. 71. Yet there are ſome inſtances where, by paſſions of the mind, a ſudden revulſion by copious blood-letting, or a vaſcular convulſion, the blood has been forced to receed back from the ſmaller into the larger arteries. And on the other ſide, where an obſtruction being formed above the valves, the blood has been known to ſlide back from the venal trunks into their ſmaller branches. But then theſe accidents are very momentaneous or ſudden, and the blood ſoon returns into its natural courſe.

§. 72. The courſe of the humours *in the lymphatic veins*, which have valves, appears both from the nature of thoſe veins and from ligatures; for every lymphatic vein tied, ſwells betwixt the ſmaller extremities of it and the thoracic duct; but grows flaccid betwixt the ſaid duct and the ligature. All the valves in theſe, like thoſe of the blood-veins, give a free paſſage for the contents to flow to the thoracic duct: for thus they admit flatus and mercury; but they make a reſiſtance, and often an obſtinate one, to any return the other way.

§. 73. *The vapours*, that moiſten the whole cellular ſubſtance, the ſteams of the abdomen and other venters, are all thus drunk up by the leaſt pellucid veins, and ſo conveyed along to the blood-veins, that their contained juices may paſs on to the heart; and from thence it is, that an œdema enſues when a vein is compreſſed by ligature; becauſe, by intercepting the courſe of the abſorbing veins by the ligature, the vapours ſtagnate unabſorbed. In the other ſmaller veſſels, we can make no experiments, but they appear conformable to what we have ſaid, both by reaſon and analogy; and are likewiſe ſupported by the experiments of water or other liquors, abſorbed out of the cavity of the inteſtines, thorax and pulmonary veſicles.

§. 74. All juices, therefore, in the human body are drove out of the heart into the aorta to the extreme parts, from whence they are all returned again to the heart by the leaſt veins; thoſe humours only excepted, which are exhaled or diſcharged without ſide the cavities of the body. But to compleat this circle, it remains for us to find out a courſe for the blood, from the right to the left cavities of the heart: but then this pre-ſuppoſes and requires us to be firſt acquainted with the hiſtory of the heart, and the pulmonary veſſels.

LECTURE V.

Of the heart.

§. 75. THE fabric of the *thorax* is a craticle of moveable bones and cartilages, which, in general, reſembles a truncated cone, as we ſhall hereafter (§. 278.) declare more at large. The lateral parts of this cone are two membranous baggs, terminated above by an obtuſe end at the firſt rib, where they lie very near together, and are diſtinguiſhed only by the interpoſed cellular ſubſtance. The obliquity of the plane, dividing theſe two bags, is ſuch, that the right is much the broadeſt, and adheres in its deſcent all along to the whole middle of the ſternum; while the left bag deſcends, not from the ſternum, but from the cartilaginous ends of the ribs. The inner central ſides of theſe bags, oppoſed one againſt the other, makes up, what anatomiſts have called, the *mediaſtinum*. [But in ſcending the mediaſtinum, is remarkably inclined towards the left of the ſternum.] Theſe bags have no where any communication one with the other; ſo that the right may be opened or pierced, and the lungs therein may be conſumed, without injuring the left. But the ſimple denſe membrane, which forms theſe bags, outwardly inveſted with the cellular ſubſtance, is called the *pleura*,

pleura, being harder than the peritonæum, eſpecially where it adheres to the back; but is ſomewhat ſofter in its fore part. The capacity of the mediaſtinum, or that interval which lies betwixt the right and left bag above, contains the thymus, and ſome conglobate glandules, fat, and veſſels. [This capacity of the mediaſtinum is much broader above, yet not inconſiderable below.]

§. 76. Below the ſame bags growing broader depart one from the other, and leave a capacity through the whole middle part of their extent, by which the ſaid bags are divided one from the other. And this capacity is that of the pericardium (§. 77.) following. But the bags of the pleura on each ſide the pericardium, deſcending both before and behind it, terminate finally on the diaphragm on which their baſe is cut off obliquely, with a deſcent from before backward; ſo that each cavity is before ſhorter upwards, as behind they deſcend longer and lower. Within theſe bags, then, play the dilatable lungs. The back part, likewiſe, of theſe bags lying near to each other, are yet ſeparated by the cellular ſubſtance, which terminates in the pericardium, and includes the aorta, together with the œſophagus or gula: and this we call the *poſterior mediaſtinum*.

§. 77. The *pericardium*, or third bag, which firſt the cellular ſubſtance, and then the conjoined pleura, looſely cover on all ſides, as an outer coat, does not, indeed, extend to the ſternum, ſince the lungs, when diſtended, cover the heart before, and interpoſe betwixt the ſternum and pericardium in their lower part, and the mediaſtinum, gradually departing towards the left ſide, forms altogether a narrow interval under the lower end of the thymus, cloſe to which the lungs meet on each ſide; but, this vital ſituation you will alter or corrupt, unleſs you are very careful in your manner of opening the thorax. The pericardium has a broad, but ſomewhat rounding baſis, which, in younger ſubjects, adheres more laxly to the diaphragm; but, in adults, it grows thereto very firmly, by the cellular ſubſtance ſpreading broader to the right, and narrower towards the left. It is ſomewhat larger than the heart, which, therefore, may move freely therein. [This membranous capſule, or fence of the heart, was never known to be abſent.]

§. 78. Upwards the pericardium grows gradually ſmaller or narrower, ending above the heart in an obtuſe conical appendix, extended over the coats of the large blood-veſſels by ſtrict coheſion, almoſt to the upper edge of the ſternum; that is to ſay, the pericardium, having reached the eight large trunks of the blood-veſſels, which come out from the heart, adheres to them in ſuch a manner, as to form cylindrical productions, embracing each veſſel on all ſides; whence it appears like a kind of ſeptum or partition, betwixt every two neighbouring veſſels. But this capſule, ſurrounding the veſſel like a ſheath, keeps its own ligamentary texture (§. 80.) but for a ſmall length; ſoon degenerating either into the cellular fabric, which, in the lungs, like a capſule, ſurrounds and extends itſelf along with all the large arteries and veins, or elſe it finally changes into the external membrane that covers the lungs.

§. 79. The *arteries* of the pericardium are either from thoſe of the thymus, which accompany the upper and lower phrenic nerves, or from the larger phrenic arteries, from the branches of the mammaries and mediaſtinals, the bronchial, œſophageal and poſterior mediaſtinal arteries. The *venal trunks* of the pericardium have a like origination, but appear with moſt evident anaſtomoſes or openings from thoſe of the right into the others of the left ſide. The *nerves* of the pericardium are from the ſuperficial branches of the cardiacs, (§. 94.).

§. 80. That which makes the proper ſubſtance of the pericardium, is a ſtrong, white, compact membrane, more robuſt than the aorta itſelf, compoſed, at leaſt, of two plates, [theſe plates are, from the denſity of the cellular ſubſtance, inſeparable by art; but the diſtinction of them appears plainly enough in larger animals, and from the interpoſed veſſels] betwixt which, the nerves of the heart, and ſome ſmall veſſels, deſcend; but, by the help of the anatomical tube, (whereby a membrane, to be divided, is tied or ſtretched over the bottom, and preſſed by a perpendicular column of water) it ſeparates into a great number of plates. Its outer ſurface, being ſpread with the cellular ſubſtance, gives it there a ſomewhat rough appearance, while internally it appears ſmooth or highly poliſhed, and moiſtened on all ſides by a watry vapour. This vapour, which we have, times without number, obſerved in the living animal, compoſes ſome, though naturally a very ſmall quantity, of a water within the pericardium; which is often a little reddiſh, and ſubviſcid or gelatinous, and, by diſeaſe, is ſometimes increaſed to an immenſe quantity; yet the exiſtence of ſuch a water here, is injudiciouſly denied by ſome. The *water* of the pericardium is of a lymphatic nature, becauſe, by the heat of fire, it hardens into a jelly; and from hence ſmall fibres and a cellular ſubſtance (§. 16.) are often formed, joining the heart to its pericardium, in inflammatory diſeaſes of theſe parts. This liquor is ſeparated without any intermediate glandules [or any viſible pores] from the ſmall exhaling arteries of the heart, auricles and pericardium; as may be proved by a ſimilar tranſudation of water, or fiſh-glue, injected into the large arteries.

§. 81. The *Uſe* of the pericardium is, to contain the heart, and to ſupport and ſtrengthen it as a fulcrum or prop, that, in contraction, the fibres of the heart may be drawn together without diſtorting the large blood-veſſels, and that it may leſs fluctuate like a pendulum every way, by altering the poſition of the body. For theſe reaſons, we find it in all animals that have a true heart. A watry vapour here bedews the heart, hotter and quicker moved than other parts, ſo as to hinder attrition and coheſion betwixt it and the pericardium; but when this vapour is dried up or deficient, the pericardium adheres either to the whole ſurface, or to ſome one part only of the heart.

§. 82. The veins, which carry back the blood from the whole body to the heart, if we except thoſe of the lungs, (which are tranſmiſſory ones) are reducible to two, viz. the cava and the porta. The *cava* is improperly named in the ſingular by anatomiſts; ſince it is no where one ſingle trunk, but partitioned obliquely into ſuperior and inferior. The lower of the two large veins, which is the biggeſt of them in man, aſcends immediately above the diaphragm from the right ſide, towards which it is a little convex or gibbous to its union with the upper cava, and together with that in its back part, forms a middle partition betwixt the right and left ſinus: but the left ſide of the venal tube degenerates into the right auricle, whoſe fibres are a continuation from thoſe of the cava.

What

What we have here ſaid of the lower cava is alſo true of the upper.

§. 83. Thus, by the meeting of the upper and lower cava, a ſinus or cavity is formed with a convexity to the right, and inwardly filled with ſtrong, fleſhy fibres, detached betwixt the two ſimple membranes, and variouſly interwove. But the ſame cavity to the left and forepart, dilates forwards into an almoſt perpendicularly oblong or oval form, and terminates above with a blind pointed end, which is free from adheſion with the heart, and lies incumbent on the great artery. This cavity alſo, like the former, has plenty of fleſhy fibres placed betwixt two very thin membranes, almoſt in a parallel poſition, and theſe form a kind of arch extended from the right to the left edge of the whole cavity, and round the anterior half cylinder of this cavity; and theſe muſcular arches are connected together by ſome of the leaſt fibres. This anterior and ſtringy part of the cavity is called the *auricle*; but that to the right and poſterior part is called the *ſinus*.

§. 84. Where the lower cava opens into the right auricle, from the tumid column of the left ſide of the foramen ovale, ariſes a moon-like membrane, naturally compleat in its figure, and from its thinneſs ſometimes net-like; and this being extended round the lower edge of the auricle, grows thinner all the way as it is incurvated to the right, but does not quite ſurround half of the auricular circumference, the cavity of which it ſerves like a partition to divide from the vena cava. This is, by anatomiſts, called *Euſtachius's valve.* The oval foramen, we ſhall deſcribe hereafter, (§. 840.).

§. 85. The blood of the upper and lower cava, meeting together in this *atrium*, or porch of the heart, (§. 83.) compoſed of the ſinus and auricle, there waits for the relaxation of its ventricle, into which it is propelled by a conſtriction of the muſcular threads of the auricle, by drawing the anterior ſemicylindrical part of the auricle into a plane; while, at the ſame time, they bring the middle arch backward, to the anterior and poſterior edge of the beginning of the heart. Thus the blood of both cavæ, being mixed together in the beginning of the heart now dſincumbered, is drove through the edges of the open valve, in ſuch a manner, as to urge the tricuſpid valves of the right ventricle cloſe to the ſides of the heart. But the blood is now hindered from returning again into the lower cava, both by the contraction of the auricle, the reſiſtance of the ſucceeding blood from the abdomen, and of the *Euſtachian valve*; and upwards it is hindered from aſcending both by the motion and weight of the conſequent blood.

§. 86. The *figure of the heart* itſelf, in ſome meaſure, reſembles half a cone, if the cone be ſplit into two longitudinally in the direction of its axis. 'Tis almoſt triangular, only the end of it is obtuſe, and the lower ſide of it is flattened, in proportion to the diaphragm on which it lies incumbent, and is thereby ſuſtained. But, in expiration, the *ſituation of the heart*, with its apex to the left nipple, is ſuch, that the convex ſurface of the cone is ſo inclined within the pericardium, under the great blood-veſſels, as ſuffices to place its thicker ſemicircular curvature, which modern anatomiſts call its *obtuſe margin*, directed to the upper and to the left ſide of the breaſt; in its lower and anterior part, the heart is alſo extenuated into a kind of edge, which is called its *acute* margin. This is the general ſituation of it in mankind; but in brutes the heart, being almoſt parallel to the larger axis of the thorax, its apex or tips only extend to touch the diaphragm.

§. 87. The whole heart is hollow, having its right or *anterior ventricle*, communicating into the right auricle and ſinus, of a more broad and ſemicircular figure, and not ſo long as the poſterior left ventricle; and it terminates in the ſhorter tip of the bifurcated apex of the heart. The mouth of this ventricle, where it opens into the auricle, is elliptical, and terminated by a white glutinous margin, more callous than tendinous; over this, plates of muſcular fibres are ſpread, and ſome fat lies outwardly upon theſe.

§. 88.

§. 88. From the ſaid callous margin is extended within the heart, a membranous ring, formed by a reduplication of the internal membrane of the auricle, extended ſo as to float within the ventricle, to which it was before continuous. But this ſame ring, in that part which fluctuates in the ventricle, is ſo ſplit or divided into three unequal triangular portions, that you may, in ſome meaſure, give them the name of valves, and count three of them in number, although they are, in fact, only continued parts from one broader ring. Theſe were, by the ancients, named *triglochines* or *tricuſpid* valves.

§. 89. That part of theſe valves, which lies next to the ſides of the heart, is ſtrengthened by tendinous fibres, which, meeting together in their courſe, are inſerted by very ſtrong cords, partly into the ſides of the heart, and partly into papillary or cylindric muſcles, which ariſe upward from the left ſide of the right ventricle towards its right ſide. The largeſt of theſe muſcular columns is that which anſwers to the biggeſt of the valves; which is both the uppermoſt, and that which anſwers to the adjacent mouth of the pulmonary artery. The leaſt of them is the loweſt, and ſeated to the right ſide.

§. 90. The uſefulneſs of this valve is evident enough; for the right auricle being contracted, by a conſtriction of the fibres in the partition betwixt the two auricles, the blood contained in the right porch of the heart (§. 85.) being impelled from the circumference towards the axis, like a wedge, ſeparates the pendulous portions of the ring, called tricuſpid valves, and preſſes them to the ſides of the heart. Thus is filled the right ventricle of the heart, while the largeſt or uppermoſt of the ſaid valves ſhuts the pulmonary artery, leſt the blood, by the weak impulſe of the auricle, ſhould flow into that artery; the blood thus received and confined within the right ventricle of the heart, is, by the ſtrong contraction thereof, more powerfully expelled into the artery.

§. 91. The ſenſible fleſh of the heart, being irritated by the quantity and weight of this warm blood, is thereby ſollicited to a contraction:. for that the heart, being irritated, will contract itſelf in a perſon dying, or even lately dead, is proved by injections of water, and inflations of air, whereby the heart, then quieſcent, is recalled to its motion.

§. 92. The heart's motion is performed by *muſcular fibres*, the originations of which, in general, are, from rings formed of the cellular ſubſtance, compacted into a callous ligament, agreeable to the deſcription given in §. 87. and with which, all the larger blood-veſſels, at their opening into the heart, are ſurrounded. From thence the fibres, which ariſe, deſcend gradually in an oblique winding courſe towards the left ſide, and forward to the apex, in many diſtinct plates, and ſometimes a little traverſing each other, the innermoſt of them being the moſt tranſverſe. In the flat ſide of the heart (§. 86.) there are few fibres, and ſo thin, that when you have removed the fat, the cavity of the right ventricle appears almoſt uncovered. That which is called the left ventricle, is, however, very firmly inveſted by the fibres; which, after ſurrounding the ſame ventricle, form a ſlight decuſſation in the ſeptum cordis with the fibres of the right ventricle, and are interwove with them. Some of theſe fibres deſcend into the cavities of the ventricles, and form there the fleſhy columns mentioned at §. 89. Others, at the tip of the heart, are wound in a vortical or whirling poſition, the two horns ending by a ſtrong faſciculus or bunch in each ventricle. A very thin and ſmooth membrane covers the external and internal ſurface of theſe fibres; but the external membrane, eſpecially where 'tis ſpread over the coronary veſſels, contains much fat beneath it. I have, for my own part, not been able to diſtinguiſh any thing more particular in the muſcular fabric of the heart, with any tolerable degree of evidence; becauſe it is the peculiar property of the fibres in the heart, to join together in branchy appendices or heaps, in ſo ſtrict union, that they cannot be ſeparated without laceration.

§. 93. But there are ſeveral eminent anatomiſts, whoſe ingenuity and communicative freedom I reſpect, who have repreſented and deſcribed thoſe fibres diſplayed and ſeparated. Namely, the external fibres of the heart, common to both ventricles, deſcending to the tip, and, then taking another courſe, to inſert themſelves into the ſeptum; others again, at the tip, to perforate the left ventricle, and return, in a contrary courſe, to the baſis, along the inner ſurface of the ſaid ventricle. But the middle fibres, betwixt the aforeſaid inner and outermoſt ones, being variouſly inclined towards the baſis, they form the ſeptum. Which deſcriptions, as they are not much different from my own obſervations, I ſhall make no oppoſition to, although I have never been able to ſee this diſpoſition of them ſufficiently manifeſt, and am acquainted with great anatomiſts, who have not herein been more happy than myſelf. [And others have given us figures and deſcriptions of ſtill different orders of fibres, of which the outermoſt run counter to the innermoſt, while the intermediate are tranſverſe.]

§. 94. Theſe fibres of the heart, like other muſcles, are furniſhed with *nerves* of their own, very numerous and of various origin. The firſt and uppermoſt are on the left ſide from the ganglion of the intercoſtal with the uppermoſt cervical nerve, from the trunk of the intercoſtal nerve itſelf, and from its middle ganglion; on the right ſide, they come almoſt entirely from the middle ganglion, and not from the uppermoſt, but, in part, from the pharyngæal branch of the eighth pair. Theſe nerves deſcend into the heart, partly on each ſide the aorta, betwixt that veſſel and the pericardium, and are diſtributed all over the ſurface; and, partly, having firſt made various ſmall plexuſſes, they deſcend betwixt the windpipe and the great arteries, which come out from the heart; and, here, the right and left cardiac nerves, make one or more plexuſſes, joining their ſides from one to the other; but ſometimes they remain diſtinct from each other. From this ſame plexus, or plexuſſes, other nervous twigs paſs betwixt the aorta and pulmonary artery to the coronary artery of the heart; others croſs the pulmonary artery, and go betwixt it and the left auricle to the coronary artery of the ſame ſide; and others, finally, deſcend behind the pulmonary artery to the left ſinus and flat ſurface of the heart. To the cardiac plexus, above deſcribed, other large nerves acceed from the fifth and lower cervicals, and ſometimes from the phrenic nerve, and from a ganglion of the loweſt cervical with the intercoſtal, to which join large roots from the loweſt cervical nerves. The laſt deſcribed nerves, which are larger, ſofter, and more tranſverſely diſpoſed, mix themſelves with the foregoing plexus. Laſtly, there are ſome ſmall branches, uncertain as to courſe and number, which join the cardiac plexus from the recurrent and eight pair of nerves, and making various inoſculations with the intercoſtals, are confounded or loſt among thoſe of the eighth pair. As for thoſe nerves, which ſome eminent anatomiſts have ſeen aſcending from the great abdominal plexus to the heart, through the foramen of the vena cava, I have never been able to find ſuch; although it is eaſy enough to diſcover the diaphragmatics in that place, having ganglions peculiar to themſelves, of which thoſe anatomiſts make no mention.

§. 95. That theſe nerves conduce powerfully to move the heart, is evident from the common nature of muſcles, and from the increaſe which follows in the heart's motion, by irritating the eighth pair of nerves, either at the brain, or the ſpinal medulla; and from the languors that enſue upon tying thoſe nerves, which proves fatal, either ſuddenly or within a few days, even though you happen to make the ligature on but a few of the nerves that come to the heart; for the intercoſtal, and eſpecially thoſe from the ganglion of the upper thoracic, cannot be tied.

§. 96. But that there are ſtill other cauſes, beſides that of the nerves, conducing to the motion of the heart, we are perſuaded from the permanent motion it exerts, while moiſt in diſſected animals, which have it of a like make with man, as in the dog, in which we have obſerved it for many hours; and in animals, having only one ventricle, the motion laſts much longer, even after the heart is cut out from all the nerves that ſupply it with any influx. However theſe cauſes may be, all our experiments agree in this, that the quieſcent heart, irritated by heat, cold, vapours, poiſons, and eſpecially the force of impelled flatus, watry liquors, wax or blood, immediately contracts itſelf, by putting all its fibres into a rapid motion, with a conſiderable ſtrength, which terminates in an entire evacuation of the heart, [by a force ſometimes common throughout the whole heart, and ſometimes affecting only a particular part of it.]

§. 97. 'Tis, therefore, evident, that the heart, ſtimulated by the impulſe of the venal blood, without other aſſiſtance, contracts itſelf. And that this contraction is convulſive, made with great celerity, and a manifeſt corrugation of the fibres; whereby the whole heart becomes ſhorter, [therefore, thoſe learned gentlemen muſt have been led into a miſtake, who aſſert, that the heart becomes elongated in its contraction] thicker and harder, ſo that the apex or tip advances towards the baſis; which, in living brutes diſſected, I have often, with the greateſt evidence, obſerved. But the heart does not appear to turn pale in this action, in ſuch animals as have a warm blood; although the muſcular ſides of the heart, at the ſame time, ſwell inwardly, and make a compreſſure on the blood, like that which we feel upon the finger, when thruſt into the contracting heart. But that the heart is conſiderably enough emptied in this action, appears from the internal ſurface being full of eminences, which exactly anſwer to oppoſite cavities, and to the thick reticular arms or columns interrupted by ſinuſſes. Finally, the apex of the heart, being contracted a little like a hook, ſtrikes againſt that part of the pericardium next the thorax. (§. 86.) [Forwards, there is alſo a pulſation from the left venal ſinus, which is, at that time, particularly filled. In expiration, the heart ſtrikes violently more upwards and forwards. The truth of both theſe we know by experience, from the touch.]

§. 98. The blood, which is preſſed by the contracted heart, endeavours to eſcape in all directions; but being drove from the muſcular ſides, towards the axis of the ventricle, by the reaction of what is lodged betwixt the venal ring (§. 88.) and ſides of the heart, the looſer ends of the ſaid ring are driven forwards, and extended inward at the ſame time. By this action, upon the whole circumference of the ring, it not only becomes extended itſelf, but, at the ſame time, throws back a part of that blood into the right auricle, which had before deſcended into the cone of the open valve, whoſe ſides, now approaching, ſhut up the venal orifice, more cloſely as the heart contracts more ſtrongly, by whoſe force the tricuſpid valves, as they are called, would be preſſed reduplicated into the auricle, if the muſcular nipples or columns did not keep down their edges, and hold them firmly by their contraction (which is the ſame with that of the heart) in ſuch a ſhape, as will extend the annexed chords of the valve, without injuring them. [After expelling its contents, the heart becomes quieſcent, merely from the abſence of a ſtimulus. For that the fibres can be able to dilate themſelves, is contradicted by inſpection, which aſſures us all the fibres of the heart exert their contraction at one and the ſame inſtant; and is no leſs repugnant to reaſon, which plainly ſhows us, that the tranſverſe ſtrings and fibres of the heart cannot act alone without the aſſiſtance of the reſt.]

§. 99. But the niſus of the remaining blood in the ventricle, now reſiſted by the tricuſpids, ſeeks another courſe; and, whilſt it derives the larger of thoſe valves, that is ſeated to the right, (§. 89.) from the ſide towards the axis of the heart, this leaves open the mouth of the pulmonary artery, which it before covered; whereupon the blood enters there, and, by preſſing the valves in the mouth of the ſaid artery cloſe to its ſides, it becomes thus filled and dilated by the blood driven into the lungs.

§. 100. To deſcribe this more particularly, from the upper and poſterior part of the right ventricle, a way leads into the *pulmonary*

nary artery, which is ſtrongly connected to the heart by a cellulous, callous ring, from whence the pulmonary artery aſcends to the right backward, and diſplays itſelf behind the arch of the aorta. The ſtrength of this artery is not extraordinary, being much weaker than that of the aorta. But from the inner ſurface of the artery, where it is joined to the heart, *three ſemilunar valves* ariſe, by a reduplication of the arterial membranes extended upwards and towards the axis, in an arch that is flat or obtuſe enough; and theſe valves always fluctuate with their edges at free liberty, in a parabolical ſhape. The middle of the edges, in each of theſe valves, is generally divided by a ſmall, denſe, callous body of a conical ſhape, but made up of inclined planes, whereby each whole valve, in itſelf reſembling an half moon, is thereby again ſubdivided into two leſs half moons. Betwixt the two membranes of the valve appear ſome muſcular or tendinous fibres, partly in a tranſverſe poſition, ſome of which hold faſt the valve to the next contiguous ſide of the heart, leaving ſometimes ſpaces betwixt them in a reticular manner. Other fibres aſcend from the baſis of the valve, and, by growing to the callous corpuſcle, draw back the ſaid valve, and open its concavity.

§. 101. Each of theſe valves, in conjunction with the ſides of the artery here diverging, intercept a ſpace, which is blind or impervious

pervious downward, but open upward in a parabolical ſhape, as we obſerved of the valves in the veins. (§. 53.) When, therefore, the blood is impelled from the ſides towards the axis of the contracting heart, it endeavours to eſcape in the direction of the ſaid axis, and, by ruſhing forth, like a wedge, betwixt the valves, preſſes their looſe ſail-like edges againſt the ſides of the pulmonary artery, ſo as run freely out of the heart. The truth of this appears from the plain fabric, from injections, and from ligatures.

§. 102. The blood now received into the pulmonary artery, goes on then to make its circulation through the lungs. That artery is firſt divided into two branches, of which the left, being leſs and ſhorter, enters directly into the ſubſtance of the lungs; but the right branch, being larger and longer, paſſes tranſverſely through the arch of the aorta, and after going a little way behind the ſaid aorta, enters the correſponding lungs of the ſame ſide. From each of theſe branches, by a multiplied ſubdiviſion, ariſe the very leaſt arteries, ſome of which tranſmit the blood directly into the continued ſmall veins, and others exhale part of its aqueous juices into the pulmonary cells. That the blood goes thus directly from the arteries into the pulmonary veins, appears evidently from their ſtructure; alſo from a ligature, which, intercepting the blood's courſe, while the heart and lungs ſtill urge it, cauſes an aneuriſmatic dilatation of the artery; and from polypuſſes, by which the mouth of the pulmonary artery being obſtructed, the right cavities of the heart become monſtrouſly enlarged, and at length burſt, while the left remain empty. Laſtly, from injections; for water, fiſh-glue, and milk, are very eaſily forced from the pulmonary artery into the vein, and from thence into the left cavity of the heart. But the direct anaſtomoſes, or final openings of the arteries into the veins in the lungs, is proved even to the ſight by the microſcope, in frogs, &c.

§. 103. Nor can the blood, which has once entered the pulmonary artery, return back again upon the heart; becauſe the valves therein (§. 100.) are of ſuch dimenſions, that, when diſtended, they perfectly ſhut up the opening at the heart, and are ſo ſtrong, that they reſiſt a much greater force than the contraction of the pulmonary artery, without being conſtrained to yield. However, ſometimes, from a greater contractile force of the artery, they grow callous, or, from a laceration of their outer membrane, a bony matter is poured in betwixt the duplicature of the valves. For when the blood, by contraction of the artery, returns towards the heart, it meets and enters the open ſail-like concavities of the valves, (§. 101.) which are, by that means, expanded and drove together towards an axis in the middle, whence the valves, once expanded, quite ſhut up the mouth of the artery, ſo as to leave not the leaſt ſlit open; for any opening, that might be left, is præcluded by the ſmall callous bodies, remarked at §. 100.

§. 104. The *pulmonary veins*, of which we ſhall ſay more herafter (§. 272.) gather into larger branches, which, at laſt, terminate in four (ſeldom two) trunks; to which, it has been cuſtomary to affix a name in the ſingular, by calling them the pulmonary vein. Theſe enter the cavity of the pericardium, from whence they receive an external covering, and are then inſerted at angles into the ſquare, left or poſterior ſinus, which is ſometimes, likewiſe, called the pulmonary ſinus. In this courſe, the upper veins deſcend, as the lower ones aſcend. But that theſe veins bring their blood towards the heart, in the ſame direction with the ſinus, into which they open, is proved by a ligature, which cauſes a turgeſcence or ſwelling, from the blood retained, betwixt the ligature and the lungs.

§. 105. This pulmonary ſinus, being firmly built of divers bundles of fibres running betwixt two membranes, has forward, and to the right, one ſingle ſide or partition, in common to itſelf and the right ſinus (§. 82.); but forward, and to the left ſide, it goes into a conical appendix, which is divided into proceſſes, or indentations, like a cock's comb, and, after two or three ſerpentine turnings, makes, what is called, *the left auricle*, incumbent on the left ventricle. This ſinus, with the left auricle, are ſomewhat leſs than the right ſinus and auricle.

§. 106. In this left ſinus the blood waits for the heart's relaxation, at which time the niſus of the blood, impelled againſt the venal valves, and the contracting ſtronger force of the ſinus, grow leſs. Then the ſinus, together with its ſmall auricle, being contracted, the blood is, by their means, drove into the left ventricle, in like manner, as the right auricle impelled its blood into the right ventricle. (§. 90.) For here, as before, a like membranous oval ring forms productions called *mitral valves*, of which there are uſually two only counted. Theſe valves are longer and ſtronger than thoſe of the right ventricle. They have each a muſcular column, often ſingle only, and joined to the tendinous threads of each valve; but they are much ſtronger than thoſe of the tricuſpids (§. 89.). And here callous knots or cartilaginous humours are often found in the tendinous ſtrings, at their originations from the membranous ring.

§. 107. From what has been ſaid then, it appears, that the ſame blood is now arrived into the left ventricle of the heart, which was a little before ſent from the venæ cavæ into the right auricle, (§. 85.) which drove it into the correſponding or right ventricle, (§. 90.) by which again it was urged into the pulmonary artery, (§. 100.) and from thence, paſſing into the pulmonary veins, was conveyed into the left ſinus (§. 104.); and out of this, we here find it driven into the left ventricle. (§. 106.) This courſe of the blood, from one ſide of the heart to the other, through the lungs, is called the pulmonary or leſſer circulation, and was known to many of the ancients, before mentioned in §. 62.

§. 108. The *left*, or poſterior and upper *ventricle* of the heart, makes up that part of its half-cone-like body, which we before called obtuſe, (§. 86.). 'Tis ſomewhat narrower than the right ventricle, a little longer, rounder, and generally of a leſs capacity within. For the contents of this ventricle are about two ounces, while thoſe of the right advance up to three. Its fabric internally is reticular, as in the right ventricle; but its force is conſiderably greater, as the muſcular fleſh that ſurrounds it, is much thicker and ſtronger.

§. 109. Again, this left ventricle, being inſtigated to motion by the impelled blood, does, from the ſame irritable nature before mentioned, (§. 87.) contract and drive its contained blood with a violent motion in the direction of its axis, and determine it towards the baſis, at the time when the tip or cone of the heart is drawn nearer to its baſis. And ſince the apparatus of the *mitral valves* is here the ſame, as before in the tricuſpids,

cuſpids, (88, 89,) the venal blood now expanding the ring from whence they ariſe, removes that valve which lay againſt the mouth of the aorta, ſo as to open a way for itſelf to the artery, in dilating the mouth of which, the ſaid blood preſſes the ſemilunar valves, there placed, againſt the ſides of the aorta, into which it ruſhes with a violent impetus.

§. 110. The *ſemilunar valves of the aorta* differ little from thoſe in the pulmonary artery, (§. 100.) only as the opening is here greater, ſo the valves are proportionably larger and ſtronger, and are not ſo often diſtinguiſhed in the middle by thoſe callous globules, or little round bodies. (§. 100.) The fibres too of the valves, both tranſverſe and aſcending, are here ſomewhat more conſpicuous.

§. 111. But we muſt now conſider, that theſe motions of the right and left auricle, with the right and left ventricle, are not performed in that ſucceſſion, in which, for the ſake of method, we have here deſcribed them; for both the auricles are contracted, while the ventricles are relaxed: ſo that the contraction of the auricles precedes the contraction of the ventricles; as we are aſſured from manifeſt experiments, on dying animals, and on thoſe whoſe living blood is cold. But both auricles are filled together in the firſt inſtant as both of them are emptied together in the ſecond inſtant; and both the ventricles are contracted together in the third inſtant, which is the ſame with the firſt; and both ventricles, being evacuated, are relaxed in the fourth inſtant, which is the ſame with the ſecond. Thoſe who have miſtakenly taught otherwiſe, have not taken the advantage of making a ſufficient number of experiments on living animals. That the auricle, near death, makes frequent palpitations, before the ventricle of the heart performs one contraction, is true enough.

§. 112. But it may be aſked, why the heart never ceaſes from *its perpetual motion*, through ſuch a number of years as there are in one's life, through ſo many days as there are in a year, and through ſo many hours as there are in a day, when, in each hour, the heart of a healthy perſon contracts not much leſs than 5000 times; ſo often are there ſucceſſive repletions followed with new contractions, perpetually in the ſame conſtant order. [Nor is there any other muſcle, beſides the heart and diaphragm, but what becomes tired and painful, by acting inceſſantly~~, even~~ for a few hours.] Different anſwers have been given to this queſtion by different profeſſors, founded either upon a compreſſure of the cardiac nerves betwixt the large arteries, or upon an alternate repletion of the coronary arteries, and cavities of the heart, &c.

§. 113. But to me the ſimplicity of nature ſeems very great in this matter. When the auricle is relaxed, it is directly filled by the muſcular force of the continuous great vein; and ſo the heart alſo contracts itſelf, when, in like manner, it is irritated by the blood driven into it from the auricle*. Therefore, the heart, having once received the blood, is contracted by that ſtimulus or irritable force, whereby muſcular fibres are excited into contraction; whereupon it empties itſelf of the blood, and, being freed from the ſtimulus thereof, immediately reſts or relaxes itſelf. But the heart being now relaxed, the auricle is in like manner irritated by its contained blood, and by contracting fills it again; while the inceſſant actions of the heart and arteries continually urge new blood into the right ſinus and auricle. [The motion aſcribed to the vena cava, is, from the right auricle, throwing back ſome blood again into the upper and lower cava, becauſe the now dying heart will not receive it all.] That this is the true ſtate of the heart's motions, is proved from actual experiment or obſervation, whereby we plainly diſcern the ſucceſſive repletions and conſtrictions made in the great vein, auricle, ventricle, and artery, eaſily ſeen in a weak or expiring animal, but more eſpecially, and more evidently in thoſe animals which have but one ventricle in the heart, as the tortoiſe, frog, ſnake, fiſhes, and in the chick hatching in the egg, which, inſtead of a heart, has only one crooked canal. The ſame is alſo confirmed from the reſting of the heart, which follows upon tying the veins, and from the return of its motion, by removing the ligatures, or by the impulſe of wind or liquors injected; and laſtly, from the perpetual contraction of a frog's heart, round or upon a veſicle of air inflating it, which air urged into it by the veſicle, it will alternately receive, and for many hours tranſmit, into the common air. Hence it appears, why the auricles, and eſpecially the right, are the laſt of all moving, if you except the next continuous part of the vena cava; becauſe the heart is irritated into motion, by the blood ſent towards it, by a contraction of the extreme parts from the cold invading the body, at which time, the lungs, deſtitute of the act of reſpiration, reſiſt the blood of the right ventricle; but the left ventricle, receiving none, ſtands ſtill for want of irritation.

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* Conformable to our author's ſyſtem, was that of the ingenious Mr. Cowper, who allotted to the blood the office of a pondus, inſtrumental of the conſtriction, or violent ſtate of the heart; from whence (according to him) it ſpontaneouſly returned to its natural ſtate of dilatation: though this is erroneouſly oppoſed by his friend Dr. Drake. Anat. Vol. II. Edit. 1, p. 403.

§. 114. Nor do I believe there is any thing more than this required to the heart's motion. For if you derive the heart's reſting, from a compreſſure of the nerves, the motion of the auricles will be an objection, whoſe nerves, in order to that, ought not to be compreſſed; and for example, in fiſh and litttle chicklings in the egg, there can be no room for a compreſſure of the nerves. If, again, you deduce the heart's reſt from a compreſſure, or occluſion of the coronary arteries, this is contrary to experience; ſince they are not covered by the valves of the aorta, and from a wound of the ſaid arteries, during the ſyſtole of the heart, the blood ſtarts out to a great height; and again, the motion of the heart ſtill continued, after they were tied by M. Chirac. But ſuch an abſolute impatience is there in the fibres of the heart to bear any ſtimulus, that, even when the viſcera are almoſt dead, this appears to have a kind of motion within its own fibres; which, beginning in a ſort of radiant points, is propagated in wrinkles into the adjacent parts: if, now, you pull out the heart, although it be growing cold, if you puncture, inflate, or irritate its membranes, the fibres of the extracted heart become corrugated in rings, notwithſtanding there is not now a continuous nerve or artery to ſupply the beating heart. [And this irritability of the heart is more exquiſite and durable, than in any other part of the body; becauſe we ſee, it may be thereby recalled into its former motions by a ſtimulus, when no other muſcle can be ſo excited.]

§. 115. But with what celerity, and with *what force the heart* drives forward the blood, is controverted, and variouſly computed. The more modern writers have raiſed their calculations upon a ſuppoſition, that for the celerity to be determined, we are to admit two ounces of blood to iſſue out of the heart with ſuch a celerity, that the part of the pulſe, called its ſyſtole, makes one third of the whole pulſation, and is finiſhed within a $\frac{1}{225}$th part of a minute; but the area of the mouth of the aorta, they have eſtimated 0.4187 parts of an inch; ſo, by dividing the ſpace filled by two ounces of blood, (3.318 inch) by the area or ſection of the aorta at its mouth, [and length of its cylinder filled by two ounces viz. $=7\frac{29309}{33180}$] the number thence produced divided by $\frac{1}{225}$, the time in which the heart contracts, they find 149 feet and two tenths of an inch for the ſpace, thro' which the blood runs in a minute, if it goes on in a cylinder with the ſame velocity it firſt had from the heart, which it does not. But the incumbent weight of blood moved by the heart, they have computed by the jet, wherein the blood ſtarts forth from the larger arteries in a living animal, being ſeven feet five tenths, and from the ſurface of the ventricle, whoſe area makes 15 inches; which produce 1350 cubical inches of blood, or 51 pounds five ounces, which preſs againſt the ventricle of the contracting heart. The heart, therefore, thus drives forward a weight of 51 pounds, with a velocity, by which it may run through 149 feet in a minute; which force it exerts four thouſand eight hundred times in an hour.

REMARK.

There is no doubt but the heart moves not only the whole maſs of blood, and other continuous juices; but alſo all the yielding ſolids; and even every individual yielding fibre is elongated by each ſyſtole: but then this is owing to the mechaniſm of the arterial ſyſtem, which makes a leaver or ſpring of very great purchaſe, for multiplying and transferring the force of the heart, which the arteries receive and apply, ſo as to produce great and extenſive effects. But then we muſt not aſcribe to the heart alone effects, which it can produce only by the aſſiſtance of the arteries. And if all circumſtances be duly conſidered, the heart's force will be found ſo far ſhort of Borelli's enormous calculation, that it will be leſs than any computation I have yet ſeen. See remark to §. 117.——As to the time in which the maſs of blood may make a compleat circulation through the heart, as it flows with an irregularly decreaſing and increaſing motion, that varies in every artery, and in every vein, proportionably to their ſeveral lengths, diameters, angles, inflexions, ſtrength, &c. no one can juſtly determine it. The return of it may be twenty times quicker through the coronary veſſels of the heart, with thoſe of the intercoſtal muſcles and diaphragm, than in many other parts: and it may move an hundred times ſlower through the leaſt veſſels of the liver, than in the largeſt veins at the heart. However, on Dr. Hales's principles, the larger arteries may ſhift their contents into the veins, and the larger veins may paſs their blood thro' the heart, once in about five or ſix minutes, in which time, the majority of the current paſſes the heart in one compleat round.

§. 116. Al-

§. 116. Although there are many particulars here (§. 115.) unthought of, which may render the eſtimate incompleat, and ſuch, perhaps, as we may never get over; and, although, the area of the ventricle be of ſo uncertain dimenſions, and the jet of blood computed from an inſufficient height, yet, if we conſider the violence, with which the blood ſtarts from ſome of the leaſt ſanguine arteries in the living animal, although we cannot eaſily determine how much of the heart's ſyſtole it aſſumes to itſelf, variations, in which, will greatly alter the computation; yet, in the mean time, it will plainly appear, that the muſcles we call the heart, make a very powerful machine.* The truth of this is evident from experiments, in which it appears to be very difficult to fill all the red blood-veſſels by anatomical injections, and quite impoſſible to fill all the ſmaller of them: yet the heart, we ſee, not only gradually diſtends all the larger, the ſmaller, and even the leaſt veſſels with blood, but alſo drives it forward through them, with a conſiderable celerity. Even, from ſome of the leaſt arteries, I have ſeen the blood ſtart forth ſeveral feet, the jet deſcribing a parabola, whoſe height was four feet, and amplitude of the projection ſeven feet. [And ſome aſſert, they have ſeen the blood aſcend from the aorta to the height of 12 feet.]

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* That is to ſay, when aided by, or acting in conjunction with the arteries.

REMARK.

Obſerve here, that the heart fills the ſmaller veſſels, not by one, but by repeated ſtrokes; or by a force multiplied in, and communicated from the coats of the great arteries, which force, as well as that of the heart, enters the meaſure or parabola of the jet of blood from an artery. See the following remark.

§. 117. Moreover, that we may make a juſt eſtimate of the heart's force in living animals, we muſt conſider what great reſiſtances that complex muſcle overcomes; we muſt compute the enormous weight there is of the whole blood, a maſs, perhaps, of fifty pounds and upwards: for all that quantity of fluids, once ſtagnant in a perſon lately drowned, or fainted away, are eaſily put into their former motion by the heart only. We muſt again conſider the great decreaſe of the blood's velocity, ariſing from the greater light or capacity of the dividing branches, (from whence the ratio of its celerity, even in the inteſtines, may be computed to only a 24th or a 30th part of its original impulſe) abates two thirds from the heart's force. And yet we ſee there are humours ſwiftly moved through much ſmaller veſſels; as for example, in thoſe of the Sanctorian perſpiration, which, in a ſubterraneous cavern, I have obſerved to aſcend ſwiftly in form of ſmoak or vapour; and the ſame celerity of the blood in the leaſt veſſels of little fiſhes, &c. is apparent to the eye by a microſcope. Now ſince the frictions, in every machine, always conſume a great part of the moving forces, much more do they in the human body, whoſe blood and juices are ſo much more viſcid or clammy than water, and drove through veſſels ſo ſmall, that they permit only a globule at a time to paſs through, and even hardly allow that, without changing their figure; but from ſo ſtrong and extended a friction, muſt neceſſarily follow a very great hindrance to the motion, whence we may eaſily underſtand, that the force muſt be very great, which drives ſo ſwiftly ſuch a prodigious maſs of fluids, over ſo many reſiſtances and decrements of the moving forces.

REMARK.

We are to obſerve here, that a very ſmall part only of theſe reſiſtances* is removed each time by any ſingle contraction of the heart; to which the arteries ſerve as a multiplying ſpring, by their elaſtic force, proportionable to their diſtention; and drive forward the blood and its continuous juices, in the ſame manner, as the air, by its ſpring, throws out a continued ſtream with a celerity proportionable to its compreſſure, in the fire-engine or forcing-pump. For, as the arterial valves at the heart, which ſuſtain a part of this elaſtic force equal to their ſurface, will admit of various apertures; the heart acts upon that hydraulic principle, whereby *any force or preſſure, ever ſo weak, by urging a fluid through an aperture, proportionably ſmall, ſhall overcome any reſiſtance, or raiſe any weight, ever ſo great.* So that whenever the arterial reſiſtance is increaſed, or the muſcular force of the heart abated, the valves of the heart are opened by a proportionably ſmaller column of blood; which, in a natural eaſy ſyſtole, is ſeldom more than half the contents of either ventricle; as in a natural eaſy expiration, the lungs ſeldom expel more than half their contained air. Hence it appears, that to allow an opening to the valves, equal to the light of the artery, and the quantity of blood expelled, to be equal to the capacity of the ventricle, §. 115. are conceſſions too great by half to eſtimate the natural force of the heart, which when reduced to but a few ounces, is yet, upon the aboveſaid hydraulic principle, able enough to carry on the circulation. To this automatic or elaſtic force, as the principal, add the vital or muſcular force of the artery. Vide remark to §. 44.

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* Equal to the opening of the valves.

§. 118. The blood being drove into the aorta, immediately finds the two openings of the coronary arteries, which lie next the arterial valves, but above them, or within the aorta; and, in conſequence of this, it ruſhes firſt of all into the ſaid coronary arteries, by which the heart ſupplies itſelf with blood. Theſe arteries are almoſt conſtantly two, which going off from the aorta next the heart, at an obtuſe angle, are diſtributed in a retrograde or contrary direction. More particularly the *right coronary* artery deſcends betwixt the aorta and pulmonary artery, and bending round the ſurface of the right auricle, it winds about the ſharp or anterior edge of the heart, whence ſpreading on the lower or flat ſide thereof, at its middle or a little further, the branches go on, and terminate towards the tip of the heart; after having firſt given its ſmall branches to the right auricle and ventricle with the lower vena cava, pulmonary vein, &c. The other ſuperior and *left coronary* artery goes out betwixt the left auricle and the aorta by three branches; one of which goes round the root of the left ſinus to the lower plane of the heart, but terminates on this ſide the middle ſeptum of the heart, and is ſpent on the left ventricle, and on the left auricle with its ſinus. In like manner, another branch is ſpent by deſcending branches on the top of the obtuſe edge or upper ſide of the heart belonging to the ſaid ventricle, where it makes circles detached to the large arteries. The third branch is ſpent deep within the muſcular fleſh of the heart. All the external arteries of the heart are followed cr ſurrounded with much fat.

§. 119. Theſe arteries communicate, by open anaſtomoſes, or inoſculations of the ſmall branches, every where about the ſeptum and tip of the heart; but they no where make a compleat ring round the heart. They terminate in a two-fold manner.

§. 120. The firſt termination of them, is into the coronary veins, whoſe branches running in company with thoſe of the arteries, have their trunks of neceſſity diſpoſed in a different courſe. The *great coronary vein* is, therefore, a companion of the left coronary artery; and is inſerted with a large opening, ſecured with valves on the left ſide of the Euſtachian valve (§. 84.) of the right auricle, the root of this ſurrounds the left auricle externally, and then accompanies the ſuperficial branches of the left artery, as before deſcribed, §. 118.

§. 121. The other coronary vein (which you may make a part of the former, ſince they have both one common inſertion) deſcends along upon the ſeptum of the heart to its flat ſide; and may be properly called the *median coronary.* The *third* bends tranſverſely round the ſurface of the right auricle, and then terminates within, or, at leaſt, very near, the large opening of the coronary vein (§. 120.) anteriorly. This vein ſupplies that part of the right ventricle, which lies in the flat ſide of the heart; and often receives thoſe nameleſs veins, we ſhall hereafter deſcribe.

§. 122. There are ſtill ſome other *anterior veins* of the heart; but one, more particularly large, goes along the adjacent edge of the right ventricle, and running for ſome length obliquely betwixt the membranes, is inſerted into the moſt anterior part of the right auricle, and ſometimes into the trunk of the upper vena cava. This anterior vein ſends off another concealed one through the root of the right ſinus, and being again inſerted into the great coronary vein, it makes a compleat circle round the heart, like the arterial circle, (§. 119.) which ſome have deſcribed, but has not yet been ſeen by me. As for leſſer venal circles about the heart, as well as the ſaid arterial one, they are not yet ſufficiently confirmed.

§. 123. But there are a great many more veins, uncertain in their number, which belong to the baſis and internal parts of the heart, to which the anatomiſt has ſeldom any acceſs, becauſe they lie concealed betwixt the origins of the large veſſels: and theſe open by numberleſs ſmall mouths into the right ſinus and auricle; and ſome, but a few only, into the left ſinus. Thus I have ſeen a particular vein, which, from a latent ſinus in the fleſh of the right auricle, has aſcended up towards the aorta and pulmonary artery, and inſerted itſelf on one ſide into the greater coronary vein. Another I have obſerved, concealed betwixt the mouth of the coronary vein and the aorta, inſerted into the right ſinus; and another through the remains of the oval foramen, and ſeptum of the two ſinuſſes, inſerting itſelf into the right ſinus; and others again belonging to the venal valves, beſides which, there are ſtill others too numerous to deſcribe.

§. 124. There are ſtill more, and much ſmaller, veins in the heart, whoſe little trunks, being very ſhort, cannot eaſily be traced by diſſections; and theſe open themſelves by an infinite number of oblique ſmall mouths, through all the numerous foveæ or little ſinuoſities and excavations, obſervable throughout the ſurface of the right and left ventricle. Theſe are demonſtrated by injections of water, wind, or mercury, made by the coronary arteries, after you have firſt tied their correſponding or accompanying coronary veins; or even by injecting into the great coronary veins, after you have firſt intercepted the openings of their largeſt trunks. For, in either of theſe caſes, there are drops of the tinctured water, bubbles of air, ſpherules of mercury, ruſhing out thro' the whole extended ſurfaces of both the ventricles of the heart. [And this, without any violence that can be ſuppoſed ſufficient to break the veſſels.]

§. 125. There are ſome who will have the coronary arteries filled with blood, not by the contracting of the heart, but of the aorta in its ſyſtole; which they think muſt be a conſequence of the retrograde angle of the blood's courſe here, and the paleneſs of the contracted heart, with a ſuppoſition, that the valves of the aorta cover or cloſe the mouths of the coronary arteries. But the two laſt of theſe are diſproved by experience, and the firſt, or retrograde courſe, can only impede or leſſen, and not intercept, the flux into the heart: for the injections of wind or mercury, into all the ſeminal and biliary veſſels, demonſtrate, that the large retrograde angles, which the veſſels often there make, do not hinder the fluids from taking their natural courſe, though they retard it. But a proof, ſtill more evident, is, that the coronary artery, and the blood ſtarting from it, make a higher ſaltus at the time when the heart is contracting.

§. 126. Concerning the reflux or return of blood from the muſcular ſubſtance of the heart, there is ſtill leſs room to doubt: for all the coronary veſſels diſcharge their blood into the auricles and ventricles, either right or left, (but leſs into the latter) by thoſe larger (§. 120 to 123.) and by the ſmaller orifices, (§. 123.) as well as by the leaſt, (§. 124.) which ſo eaſily tranſmit the injections, after you have firſt tied the larger coronary veins. The circulation through theſe veſſels ſeems to be compleated in the ſhorteſt ſpace of time that can be in any part, from the great velocity the blood receives from the heart itſelf, urging the ſame through its own ſubſtance. But that the whole contents of the veſſels are cleared in each contraction, does not ſeem to me probable; for the blood-veſſels of the heart do not look pale enough in that action to produce ſuch an effect, as an entire evacuation. ----There is a very free or open paſſage from the arteries of the heart into the cellular ſubſtance, or fat which ſurrounds it.---If you aſk, what are the uſes of thoſe leaſt or ſhorteſt veins, which open obliquely thro' the ſurfaces of both the ventricles? (§. 125) they ſerve to return the blood of thoſe deeply ſeated ſmall arteries, within the muſcular ſubſtance, which have no correſponding veins running by their ſides, like thoſe on the ſurface.

§. 127. The humours of the heart, which are thinner than blood, return by the valvular *lymphatic veins*, which accompany the coronary blood-veſſels, and aſcend towards the thoracic duct and ſubclavian vein, but are very rarely to be ſeen.

REMARK.

From what has been ſaid, it appears, that the force of the heart is manifeſtly greateſt in thoſe who have ſtrong fibres, not too eaſily irritable, with a pulſe large and moderately ſlow. For the number of pulſes being given, the ſtrength of the body, in health and diſeaſe, will be as its magnitude, if the arteries are duely pervious; and if the magnitude be given, the patient's ſtrength will be as the ſlowneſs of the pulſations, if there be no obſtructing cauſe at the heart. So the ſtrength will be in a ratio, compounded of the magnitude and ſlowneſs of the pulſe. Thus the perſon's ſtrength, and the arterial reſiſtance, with the tenacity of the humours, being the ſame, the quantity of the heart's contraction will be as its irritation, from the plenitude and tenſion of its ventricles. The arterial reſiſtance and heart's plenitude being the ſame, its contraction will be as the nervous or muſcular ſtrength of the body. Or the heart's ſtrength and plenitude being given, its ſyſtole will be as the reſiſtances inverſely.——If the heart weakened throws out leſs than it receives, the pulſe quickens to compenſate the want of magnitude: and ſo the heart may labour with oppreſſion, either (1.) from the venal preſſure increaſed. (2.) From the arterial reſiſtance augmented. Or (3.) from a nervous weakneſs of the muſcular ſtrength or vital powers. And theſe make the immediate cauſes of fevers, which reſult again from changes made by the nonnaturals, either in the automatic and muſcular powers of the heart and arteries, in the encephalon and nervous ſyſtem, or in the quantity and quality of the blood, and principal humours thence ſecreted.

LEC-

LECTURE VI.

Of the common offices of the arteries.

§. 128. THE blood is thus drove from the left ventricle of the heart into the aorta, which takes its courſe firſt a little towards the right, and then to the left in an arch, that is very ſharply bent; and here the maſs of this purple fluid ſtrikes firſt againſt the right ſide, and is then reflected to the left ſide again of the aorta, whence flowing in a vortical or whirling motion, as much as that full veſſel will permit, it goes on through the arteries, with an alternate colliſion againſt, and repercuſſion from their ſides.

§. 129. Theſe beating veſſels are, in a living perſon, *always full of blood*; ſince the jet or ſtream, that ſtarts from an artery, is not interrupted by alternate ſtops, while the heart reſts or relaxes itſelf, but it flows on, in a continued thread; add to this, that the microſcope ſhews the arteries, in living animals, to be full, both in their ſyſtole and diaſtole; nor can the circular fibres of the arteries ſo far contract themſelves, as to entirely evacuate theſe tubes. Since, therefore, a new wave or column of blood is ſent into the arteries already full, although it bear a ſmall proportion to the whole maſs contained in the arterial ſyſtem, throughout

out the body, hardly ever exceeding two ounces; yet, by its immediate contact with the precedent wave or column, which moves ſlower, as it gets farther from the heart, it conſequently drives the ſame forwards, and diſtends or dilates the arteries, urging the convex parts of their flexures outwards, and cauſing their ſpiral waves to be more ſerpentine, as injections demonſtrate to us. This dilatation of the artery, whereby its light or capacity is changed from a leſs to a greater circle, is called the *pulſe*; the *diaſtole* or dilatation of which, is an expanſion of the artery, beyond its natural diameter. This being the proper or characteriſtic action of life, reſults from the heart only, and is in no wiſe natural to the arteries left to themſelves. Hence, when the motion of the heart is intercepted, whether by aneuriſm, ligature, or otherwiſe, there is no pulſation of the arteries to be felt; and from hence too, there is a ſudden ceſſation of the pulſe, by a wound through the heart, in a living animal.

§. 130. The *ſyſtole*, or contraction of the artery, immediately follows the ſaid dilatation of it. Namely, the heart, having emptied itſelf, and removed the ſtimulus of the blood, directly comes into a ſtate of relaxation or reſt. But the artery, at this ſame time, by its innate elaſticity, and contractile power reſiding in its circular fibres, (§. 30.) irritated likewiſe by the ſtimulus of the impelled blood, enters into a ſtate of conſtriction, by which as much blood is driven out from its capacity, as ſerved to dilate it beyond its mean or middle diameter: which quantity of blood is either forced into the ſmaller and ſcarce beating arteriolæ, or elſe returned into the veins; becauſe the reaction, from the reſiſting ſemilunar valves of the aorta, will determine the blood that way from the heart, §. 104. So ſoon as the artery has freed itſelf from this wave or column of blood, being no longer ſtimulated by diſtention, it directly collapſes by its own proper contractile force, and is now again ready to yield to a new wave or column of blood, ſent into it from the heart; whence follows a repeated diaſtole, or dilatation of it, as before.

§. 131. That the arteries thus contract, and, by that force, drive forward their contained blood, is proved evidently from their ſtrongly contractile nature; from the apparent diminution of the diameter or dilatation they receive from the heart; from the evacuation that follows, by the proper force of the artery itſelf, driving out all the blood that is contained in the lateral branches, betwixt two ligatures; from the greatneſs of the jet of blood, that ſtarts from an artery, even while the heart is relaxed, and at reſt; from the ſtrength or force with which eminent anatomiſts have obſerved the blood thrown out of the tied aorta, below the ligature; from the evacuation, which the arteries make of their contained blood, even after death, into the veins, whereby theſe latter appear much fuller than the arteries; and laſtly, from the conſiderable jet or ſaltus of blood, that iſſues from a large artery in an animal, even after death, amounting to the height of two feet; to which add, the convulſive contractions of the animal, in which the artery is thus wounded, and the remarkable cloſings of the mouths of divided arteries in wounds, [and a ſphacelation of the limbs, from an oſſification of the artery; whence the veins become diſtended.]

§. 132. The great ſwiftneſs of the blood's motion, (§. 115.) being ſuch as carries it above two feet, in the ſpace of a ſecond of time, and the conſtant plenitude of the arteries, render it impoſſible for us to perceive any ſucceſſion in the pulſes of different arteries; whence all the arteries of the body ſeem to beat at one and the ſame inſtant, whilſt the heart ſtrikes againſt the breaſt; and yet there is certainly a ſucceſſion in the ſyſtole of the arteries, by which the aorta ſeems to contract in the ſame order ſucceſſively, as it is filled by the blood, expelled from the heart; ſo that the part of the artery, next the heart, is firſt conſtringed, and thence gradually the arterial contracting force proceeds to the extremities. An inſtance of this we have in the inteſtines, and the ſame is evident to the eye in inſects, who have a

long

long fiſtulous and knotted heart, manifeſtly contracting in a ſucceſſion from the beginning to the end. But the mind cannot diſtinguiſh the leaſt points of time, which are the meaſures of this ſucceſſion.

§. 133. If it be aſked, where this pulſation ends? we anſwer in the leaſt arteries, and cylindrical originations of the veins. Certain we are, that the lights or ſections of the arteries, compoſed by the aggregation or ſum of their tranſverſe ſections, as they divide farther, in their courſe, from the heart, greatly exceeds that of the aorta; ſo that ſince the ratio, or leſs proportion of the trunks to their branches, continually diminiſhes, as they make leſs ramifications, and this, in a variable or uncertain proportion; the difference of that ratio or proportion will be the greateſt, betwixt the light of the aorta at the heart, and the ſum of the ſections of all the ſmall arteries, where they are leaſt, in the extreme parts of the body. Again, (2.) the proportion of the arterial membranes, or coats in thickneſs, with reſpect to their bores or capacities, is greater, as the arteries grow leſs; and is largeſt in the leaſt of them, which tranſmit only one globule at a time. The truth of this, is proved from anatomy, and the forcing of air into the arteries, by which they burſt always more difficultly, as they are leſs; and from the calculation itſelf, by which the magnitude of the leaſt arteries is determined from the globules diſtending their two ſemicylindric membranes. Add to this, (3.) the friction of the juices through the leaſt veſſels, inflected and meeting together in angles; which friction, even in the moſt fluid water, running through long pipes that are ſingle, and in a direct courſe, greatly diminiſhes the velocity, and more in proportion, as the tube is of a leſs bore; while again, as the artery is leſs, there are a greater number of globules rubbing and grating againſt its membranous converging ſides. But, moreover, (4.) the *inflexions and folds*, or plates of the veſſels, greatly ſlacken the blood's motion; ſince always ſome part of the impelling force is ſpent and loſt in removing the convex parts of the folds, and changing the figure of the inflected veſſel. Laſtly, (5.) the great viſcidity or tenacity of the blood itſelf muſt be conſiderably allowed for, ſince, by reſt only, it directly hardens into clots; and ſince it is from the circulatory motion only of the blood, that this mutual attraction of coheſion, in its parts, is overcome, ſo as to hinder it from adhering together, or to the ſides of the arteries; for ſo we find it adhere in aneuriſms and wounds of the arteries, or elſe the globules clot together, as we ſee uſually after death. From all which conſiderations, you will obſerve, that the blood meets with the greateſt retardation in its courſe, in the leaſt veſſels. [And ſurgeons know, that a ſmall branch, near the heart or aorta, bleeds more dangeroufly than one much larger, that is more remote.] We may eaſily perceive the amounts of this retardation will be very conſiderable, although it be difficult to make a juſt eſtimate of it. In the larger trunks, the blood of a living animal flows with the rapidity of a torrent; but, in the leaſt branches, it creeps along very ſlowly, with its globules trailing only one at a time, and apart from each other; ſo that in the leaſt, it begins to put on a ſtate of coagulation. Thus in a frog, the blood runs through the capillaries but two thirds of an inch in a minute; and in an eel, it moves through four inches in that time. Compare this with what is ſaid at §. 58, 115 and 140.

§. 134. The pulſe, therefore, or dilatation of the artery enſues, becauſe the anterior wave or column of blood moves on ſlower, while the ſubſequent or poſterior wave comes faſter; ſo that the precedent is an obſtacle to the conſequent blood, §. 129. But ſince the force of the heart weakens as the blood goes on, and the contractile power of the arteries increaſes, therefore the diſproportion of celerity, betwixt the antecedent and conſequent waves or columns of blood coming from the heart, will be continually leſſening, with reſpect to the blood that is urged on by the contraction of the ſmaller veſſels, 'till arriving at a part where there is no exceſs or difference, it will there ceaſe to make any pulſation of the artery; becauſe here the anterior and conſequent blood flow evenly, or with the ſame cele-rity in one continued thread. But this place of equality, in motion, cannot be in the larger and more conſpicuous arterial branches; for in them, the wave, laſt coming from the heart, moves quicker than what went before; as is evident from the inflammatory pulſation of them, eſpecially in the ſmall arteries of the eye. But in the leaſt red arteries, the pulſe at length begins to vaniſh. This is evident from the equable motion of the blood, often ſeen by a microſcope through the arteries of a frog. But in the leaſt veins, viſible to the eye, there is no ſenſible pulſation or accelerated motion of the blood, whilſt the heart contracts, demonſtrable, either by the microſcope or any other experiment.

REMARK.

With regard to the pulſe of the arteries, it appears to us to depend more on the action of the arterial coats than is commonly imagined. For example, if the parts of a viſcid fluid run into coheſion, ſo as wholly, or in part, to ſhut up the light of a converging tube, this will be ſo far from accelerating the flux through the dead tube, that it will either proportionably abate, or wholly intercept it; whence the doctrine of inflammation, as ariſing from a mere obſtruction, has been exploded by Dr. Gorter and others (who, by ſtanding on good preceptor Boerhaave's ſhoulders, have, in ſeveral particulars, been able to ſee further than himſelf.) But an obſtructing matter in a living artery, which is an irritable muſcle of conſiderable force, will there act as a ſtimulus, whereby a greater flux being derived into the nervous and vaſcular fabric of the arterial coats, that obſtructed artery will contract more violently, or to a leſs diameter than the reſt, as will, likewiſe, all the branches coming from the artery below the part ſtimulated: but this ſeries of the arteries being thus more empty than others at each ſyſtole, as ſoon as their contraction is over, they will proportionably make a leſs reſiſtance than other arteries, to the blood that comes to fill them; which, thus flowing in a greater quantity, will alſo cauſe a larger diaſtole, which, joined with a larger ſyſtole, is the eſſence of fever and inflammation. We are, therefore, not to imagine, the blood is equally accelerated through all the arteries in fevers; for wherever there is pain or local inflammation, the acceleration will be greateſt through the arteries of that part; although, from communication and conſent, it will be alſo accelerated in a leſs degree through the whole ſyſtem. Dr. F. Hoffman makes this local and univerſal increaſe of action in the arteries, the proximate cauſe, not only of fevers and inflammations, but of moſt other diſorders, under the denomination of ſpaſms or convulſive conſtrictions; and contents himſelf in accounting often for the production of a diſeaſe, by reſolving it into this ſource: whence his theory is leſs uſeful and inſtructive than the Boerhaavian, which takes particular notice of, and claſſes more accurately, the many proximate cauſes in the habit, and numerous remote ones without, producing this ſpaſm as an effect; the cure or removal of it being various, as the cauſes ſhall direct. See remark to §. 44.

§. 135. It follows, therefore, that the force of the heart altogether ceaſes in the beginning of the veins, ſince there is very little of it remains in the leaſt arteries, and in the leaſt of the conſpicuous veins, nothing at all of it can be found. And that the pulſe may be thus ſpent or loſt, merely through the narrowneſs of the leaſt veſſels, is proved by the experiment, in which a pipe, fixed in a leathern tube, and driving forth water in a continual, but ſtarting ſtream, does, by a ſponge, fixed round the mouth of the ſaid tube, cauſe the water to iſſue forth in an even ſtream, without leaping, through the ſponge: and the ſame is evident from another experiment, in which the ſame thing happens, by injecting the meſenteric arteries with an alternate impulſion of water; for then the water flows out through the veins, in one continued even ſtream.

§. 136. The *pulſe* is, therefore, the meaſure of the powers, which the heart ſpends on the blood; becauſe it is the immediate and full effect of thoſe powers. Hence all things conſidered as alike, the pulſe is *ſlow* in the moſt healthy people, where there is no ſtimulus, nor any unnatural reſiſtance to cauſe the effect of a ſtimulus, but the heart is at liberty to ſend forwards the blood with eaſe. A *large* pulſe is cauſed by fulneſs of the artery, joined with a ſtrong force of the heart. But a *hard* pulſe denotes ſome obſtacle or ſtimulus; or elſe, that the heart's force is increaſed with a greater thickneſs of blood, or a greater rigidity of the artery. A *quick* pulſe denotes ſome ſtimulus, obſtacle, or greater ſenſibility or irritability of the heart. 'Tis beſt felt where the artery lies expoſed bare to the touch, upon ſome reſiſting bone; but obſtructions ſometimes render the pulſe perceptible, where it is never ſo naturally.

§. 137. The pulſe is ſlower in animals, as they are larger or more bulky, [becauſe the heart is proportionably bigger in the ſmaller than in the larger animals] and becauſe the heart is obliged to drive the blood to a greater diſtance; whence the reſiſtances or frictions ſeem to be increaſed, in the more bulky, over the force of the heart. Hence, ſmall animals are more voracious, and large ones, as the whale and elephant, eat leſs. The pulſe of a healthy perſon, riſing in the morning, beats 65 in a minute; but, after the fatigue of the day, it will in the evening beat 80 in that time; and again, by the night's reſt or ſleep, it will become gradually leſs frequent, 'till, in the morning, you will find it returned again to its primitive number of 65. For the voluntary motions of the muſcles, and actions of the external and internal ſenſes, urge the venal blood on to the heart, which, being thereby oftner ſtimulated, makes more frequent contractions. This is the cauſe of thoſe paroxyſms or fits of increaſe, obſervable in all fevers towards the evening. For ſleep not only retards the motion of the blood, but of all the other humours and actions in the body whatever.

REMARK.

This is one of the curious obſervations of Dr. Hales, viz. that the pulſe is quicker in ſmall animals, and ſlower in larger. In his Hæmaſtatics, he found the pulſe of a horſe ſlower by half than in a man, viz. 32 only in a minute; whereas in a dog, the pulſe beat 97 in that time; and in a ſheep 65, i. e. about the ſame as in a man ſleeping. And this we ſee is conformable to the blood's heat, meaſured by the mercurial thermometer of Farenheit's ſcale, as the late Dr. G. Martine has ingeniouſly obſerved. For the blood in oxen, horſes, and other large animals at reſt, being five or ſix degrees cooler than in us, will not riſe to our heat, i. e. gr. 96, but by a tolerable degree of exerciſe or labour, which they can thus better endure: whereas dogs, cats, and fowls are five or ſix gr. hotter than we (viz. about gr. 102.) and the latter, when ſitting or brooding on their eggs for young, are ſtill four or five gr. hotter, viz. 107 or 108, which is commonly the heat of our blood in the fit of an ague; where it is obſervable, that during the greateſt ſenſe of cold-chill, the blood is three or four gr. hotter than in health, after which it gains four or five gr. more in the height of the hot fit, viz. gr. 104 or 5; but in violent ardent fevers, where the pulſe beats 140, the blood's heat will ſtill be four or five gr. higher, viz. gr. 110; i. e. two or three gr. more than equal to a brooding hen or pidgeon, and within three gr. of the heat that ſcalds a delicate or tender hand. But ſuch an heat is in no danger of hardening, but of putridly diſſolving the blood or ſerum, which our good preceptor Boerhaave miſtook in his chemiſtry; for to indurate ſerum or the whites of eggs, takes near 50 gr. more of heat. Nor is the pleuritic or inflammatory cruſt cauſed by a greater heat, but from a greater ſtagnation of the blood in ſome veſſels, while it runs faſter through others; by which the lymphatic and ſerous globules, with the nutritious glue, §. 15. retaining leſs motion from their leſs denſity, run into filamentary concatenations and coheſions.

§. 138. The pulſe is more quick or frequent in children, as they are younger, and becomes afterwards ſlower in perſons as they grow older. The ſalient point of an ovum beats 134 in a minute: new-born infants have their pulſe 120 in that time, and from thence down to old age it grows ſlower, to 60 in a minute. A feveriſh pulſe begins from 96 per minute, and we count the pulſe has but a moderate celerity in fevers, or laborious exerciſes of adult perſons, if it does not exceed above 110 or 120 in a minute; but 'tis exceſſive at 130 or 140, which is the number of the pulſe, with which a perſon dies. The pulſe beats ſlower in winter, and quicker in ſummer, by about 10 ſtrokes per minute; and under the torrid zone, it grows quicker to 120. The different paſſions of the mind variouſly accelerate, retard, and diſturb the pulſe.

REMARK.

Here we may obſerve, that the blood's heat or its velocity are neither of them, in all caſes, proportionable to the quickneſs of the pulſe; but more denſity or proportion of craſſamentum in the blood, with more magnitude of the pulſe, or diſtention and elaſtic force of the arteries muſt concur; the defect of which is a balance to the great celerity of the pulſe in infants, which would otherwiſe be the cauſe of a high fever in them, as well as in adults. But as they make all their own red blood, even in the womb, and receive none from the mother; the largeſt globules which generate the heat, and the elaſtic force of their veſſels, are at firſt inconſiderable, and as theſe advance by age, the celerity of the pulſe abates; whence the heat and velocity of the blood are continued nearly the ſame.

§. 139. Through the leaſt veins the blood moves on very ſlowly, partly by force of the heart, which, in ſome meaſure, ſtill remains in it; and partly, by the contractile force of the arteries. The firſt is proved by a renewal of the motion of the blood, in perſons drowned; where, merely by exciting the action of the heart, the whole maſs is driven forwards. But the contractile force of the artery is proved by the ſphacelation of the limbs, whoſe arteries are become oſſified; [by the continuation of life from this force, after the heart has been oſſified or conſumed; and again, from the blood continuing to move by this force in the tail of a frog or fiſh, after it has been cut off ſometime]; from the turgeſcence of the veins in general, and particularly in the liver, by this force; and from the progreſſion of the blood, in a tied artery below the ligature, into and through the veins of any limb to the heart, by whoſe force it cannot, therefore, in that caſe, be drove on. But the different ſmall times of theſe arterial contractions cannot be diſtinguiſhed by the eye, they are ſo very minute, though reaſon aſſures us of their difference; and as to any perceptible difference in the larger veins,

that

that is confounded by the actions of the adjacent muſcles and incumbent arteries, §. 141. [But after death, the blood continues to move, in part, alſo by its own gravity, and by the elaſticity of the air generated, or extricated by putrefaction.]

§. 140. But the blood moves on faſter in the larger veins. For whenever the impelling powers remain ſufficient or the ſame, and the conveying ſmall veſſels are rendered narrower, the motion of their contained fluids muſt of courſe be accelerated; ſince the ſection of the venal trunk is much leſs than that of all its branches, in the ſame manner as that of an artery is leſs than the ſum of the branches into which it divides. Therefore, if the motion of the venal blood loſes nothing in its way, the proportion of its celerity in the vena cava, to its celerity in the veins of the thirtieth diviſion, will be thirty times greater in the former, in proportion, as the conjunct lights of all the ſmall veins exceed the light of the cava. In like manner too, the friction or attrition of the blood in the veins, and its contact with their ſides, diminiſh.

§. 141. But ſince the blood moves thus ſlowly in the leaſt arterial veſſels and incipient veins, and as the weight of the blood itſelf, in many places, wonderfully hinders its return to the heart, while, at the ſame time, the very thin coats of the veins have but little contractile power to be expected from them; therefore, nature has uſed various precautions, leſt, from the ſlowneſs of its motion, it ſhould any where ſtagnate or concreet. To obviate this, ſhe has not only furniſhed them with valves, but alſo ſupplied the veins with more watry vapours and fluxile lymph, than ſhe probably ſent by the arteries, if we conſider the great exhalation that is made from the arterial blood in the lungs.

§. 142. She has, therefore, likewiſe placed the veins near the muſcles, that, by the turgeſcence or contractions of the latter, the veins may be preſſed; and ſince, by reaſon of the valves, (§. 52 to 57.) any preſſure upon the veins muſt be determined towards the heart, (§. 55.) therefore all this force will be entirely employed in accelerating the return of the blood to the heart. From hence proceeds that wonderful quickneſs of the pulſe, (§. 137.) heat, and redneſs of the body, with a ſhort and laborious breathing, that attends the muſcular motions or violent exerciſes of body.

REMARK.

The contractions of the aorta appear to urge forwards the blood from the heart, by ſucceſſively acting towards the extremities; whence the elaſticity of the arteries proves a great help to the motion of the blood, and for keeping it in an even ſtream, like the jet of a fire-engine. In a ſtate of reſt, the veins uſually contain above twice as much blood as the arteries; and as they eaſily dilate upon violent exerciſe, by which the larger arteries become almoſt empty, but the ſmaller very full; they will, upon occaſion, enlarge their capacity with reſpect to that of the arteries, as two and an half to one, which proportion they ſhow by injections; but then you muſt conſider this, as a ſtate of the utmoſt violence and fulneſs. However, upon occaſion, the veins will, without much difficulty, dilate, as a reſervoir to the right ſide of the heart, ſufficiently to hold four or five pounds of blood above their uſual quantity, that in reſt ſerves to fill the larger arterial trunks. For unleſs there was a proviſion for this redundant quantity, which, by violent exerciſe, is brought from a ſlow motion in the cells and leaſt veſſels, into a quick rapid circulation in the trunks and large branches, the animal uſed to much reſt would, by violent exerciſe, be ſuffocated by a rupture or other extravaſation in the lungs, brain, eyes, liver, &c. where the veſſels reſiſt leaſt, or are of the tendereſt fabric. This being conſidered, as there is ſo ample and wiſe a proviſion for preventing the fatal effects of ſudden fullneſs, by the eaſy dilatability of the veins, I am perſuaded, many of our modern apoplexies come from one or both the carotid or vertebral arteries, being cramped with a convulſive force, as in other muſcles, by which they urge forwards their contents, from the part where the cramp begins, with ſuch violence, as ſuffices to cauſe a rupture or extravaſation from the extremities of that trunk: and this is the reaſon, why bleeding is often of ſo little uſe to remove the cauſe, which would ſooner remove by a more painful ſtimulus, (as ſome burning cinders put directly to the hands or feet, 'till bliſters, purges, clyſters, &c. can be got). In a word, as nervous diſorders have increaſed upon us of late years to an aſtoniſhing degree, ſo moſt of our apoplexies, of late, are of the nervous kind. A ſimilar arterial cramp in the lungs cauſes an hæmopthoe and aſthma; in the liver, a jaundice; in the gula and alimentary tube, the hip and hyſterical fits, &c.

§. 143.

§. 143. Morever, thoſe muſcles, which conſtantly purge or preſs violently the contiguous viſcera on all ſides, that are contained in any of the common venters or cavities, do all of them powerfully promote the return of the venal blood to the heart. Such an effect has the conjunct preſſure of the diaphragm with the abdominal muſcles, in reſpect to the abdomen. Laſtly, the pulſations of the arteries, which run every where contiguous and parallel by the ſides of the veins, have no inconſiderable effect in promoting the return of the venal blood; ſince, as we have before ſhewn, any impulſe, acting on the veins, can determine their blood to the heart only. V. §. 53 to 57.

§. 144. By theſe means, a ſort of equilibrium obtains betwixt the arterial and venal ſyſtem, and betwixt the trunks and their branches, whereby the blood in a healthy perſon, uſing ſufficient exerciſe of body, moves on with ſuch a velocity, as ſuffices to deliver as much of the purple fluid in every pulſe by the vena cava to the heart, as is equal to what is ſent out by that great artery the aorta. But reſt or inactivity of body, and a weakneſs of the contracting fibres of the heart and other muſcles (among which, the arteries themſelves (§. 44.) are included) frequently render this motion of the venal blood more difficult. Hence follow varices and the piles in women with child; which latter is much occaſioned from the deficiency of valves, in the veins of the porta. And from hence ſpring, even the ſymptoms of fullneſs, and the menſes themſelves. And when the veins too ſlowly return their blood to the heart, the ſubtle vapours from the leaſt veſſels irrigating the parts, being thus reſiſted, or ſcarce able to return to the heart, are obliged to ſtagnate; whence proceeds that frequency of œdematous and pitting ſwellings of weak people.

REMARK.

The contents of this ſection are of the laſt importance, as a general key to the more proximate cauſes, and the moſt rational treatments of diſeaſes in general. We ſee hence, that the way to health is in moderation betwixt too much or too little motion or circulation of the blood, and its juices, through the veſſels; to attain which, a perſon muſt dedicate, at leaſt, one third of his life to ſleep, another to briſk exerciſe, and the remainder to reſt and refection: exceſs or neglect in either of which, in conjunction with other cauſes, will, by ſubſtracting too much from the blood's motion, haſten one's end, by chronical and nervous diſeaſes; or, by too much acceleration of its motion, will have the ſame effect, by acute inflammatory diſeaſes, and their conſequences. An idle perſon, that lives plentifully, ſhall breed too much juices, which will lodge where there is the leaſt motion and reſiſtance, i. e. in the cellular ſubſtance and ſmaller veſſels; if now, by a little more heat and exerciſe than uſual, theſe are driven into the larger trunks, which have a ſmall ratio to their branches, a ſuffocated plethora (*ad vaſa*) is changed into one excited (*ad vires*); the conſequences of which are pains, hæmorrhages, fevers, and ſymptoms without number; becauſe a plethora ſoon cauſes a cachochymia, &c.

§. 145. The *effects* which follow from the motion of the heart and arteries upon the blood, are various, which may be deduced and eſtimated from the cauſes themſelves of thoſe effects: if we compare together the blood of a living and of a dead animal, that which is healthy with that which is diſeaſed, and that which is inert, or too little moved, with that which circulates too ſwiftly.---For we obſerve, that, in the living, the blood is, (1.) Conſiderably warm or hot. (2.) It looks red, with a ſort of purple florid hue. (3.) It ſeems to be homogeneous or uniform, and alike in its parts, though they are really mixed, and of different principles. (4.) 'Tis made up almoſt entirely of globules. (5.) It flows very readily thro' the leaſt veſſels; from whence being drawn, (6.) it exhales a volatile vapour, which we ſhall particularly deſcribe, §. 155.---In the dead animal, which has not yet begun to corrupt or putrify, we obſerve, (1.) that it has loſt a great deal of its redneſs. (2.) That it ſeparates into a more denſe and a more thin ſubſtance. (3.) That it exhales no vapour. (4.) Being drawn out from the veins, it congeals either all or the greateſt part. But even in the living animal, when very weak, where there is ſome pulſe or reſpiration, though ſmall, we find the blood cold, even to a conſiderable degree. If, again, you compare the blood of a human perſon, unactive both in body and mind, with the blood of one that is addicted to violent exerciſe, you will obſerve the latter has, (1.) A greater heat. (2.) A more intenſe redneſs. (3.) A ſubſtance more compact, and ſpecifically heavier. And, (4.) The volatile parts more abundant. All which appearances ſeem manifeſtly the effects of the motion of the heart and arteries, ſince they proportionably increaſe and diminiſh with that motion, and diſappear when that ceaſes.

§. 146. That we may underſtand the manner in which theſe appearances are produced, in the blood, we muſt conſider what are the effects of the heart impelling the ſame, and of the arteries alternately compreſſing and urging it forward. And firſt we ſee, that the heart drives the blood into the arteries with a celerity which exceeds that of the moſt rapid rivers, (§. 115.). With a confuſed or vortical motion, the heart thus throws the blood into the crooked or inflected arteries, in ſuch a manner, that the right globules, expelled through the opening of the aorta, ſtrike againſt the left ſide of the artery, from whence being repelled, they incline towards the right ſide, whereby all the particles of the blood are agitated with a confuſed or turbulent and whirling motion. The blood, thus impelled againſt the flexile and curved ſides of the arteries, of neceſſity dilates or diſtends them into a greater convexity; and laſtly, in the ſmaller veſſels, capable of receiving only one or a few of the blood-globules, all the ſaid globules come ſo intimately into contact with, and grate againſt the ſides of the ſaid artery in all their points, that they are even obliged to change their figure, in gaining a paſſage into the veins.

§. 147. But the arteries, by their elaſtic force, reacting upon the impinging blood, repel the ſame from their ſides towards the axis of their light or capacity; and, at laſt, tranſmit every ſingle particle of it through the circular mouths of the leaſt veſſels, by which the arteries and veins join together.

§. 148. There is, therefore, a moſt prodigious degree of friction, as well of the blood-globules againſt the ſides of the arteries, as of the arteries themſelves, contracting round the blood, like an obſtacle; to which, add the attrition of the particles of the blood amongſt each other, by the confuſed and vortical motion with which they are propelled. The effects of this friction may be computed from the viſcid and inflammable nature of the blood itſelf, from the narrowneſs of the veſſels, thro' which it runs, and from the ſtrong impulſion of the heart, joined with the powerful reaction of the arteries; to which, add the weight of the incumbent parts, raiſed by the force of the arterial blood. This friction generates a fluidity in the blood, by perpetually removing the points of contact in its globules, and reſiſting their attraction of coheſion. By deficiency herein, the blood coagulates in the veſſels before death; and from hence, the loſt fluidity of the blood is again reſtored, by recovering the motion of the heart, as we are taught by experiments made on living animals. We muſt, likewiſe, own it for the generating cauſe of heat, which conſtantly ariſes from an attrition of the parts of all fluids, even of air itſelf, by experiments; but much more does this attrition heat in the elaſtic and combuſtible animal juices, which are denſer than water, and compreſſed with a conſiderable force, by contractile and converging tubes. [Is not the truth of this ſufficiently evidenced, by the blood's being warm in thoſe fiſh which have a large heart; and cold in ſuch as have a ſmall one? from the more intenſe heat of birds that have a larger heart, and more frequent or quick pulſations? and from the increaſe of animal heat, that enſues from exerciſe of all kinds, and even from bare friction of the parts?] That this animal heat is generated chiefly in the lungs, we are perſuaded by many arguments, which we ſhall propoſe, when we come to ſpeak of the reſpiration. At the ſame time, by this rotation and mutual attrition, the particles of the blood acquire their ſpherical figure; and even the filamentary, rough, and irregular ſhaped particles, having their eminencies, in a great meaſure, ground ſmooth, approach nearer to the nature of ſpheres. But again, the fragments, from the ſurfaces of the irregular ſhaped particles, will, by this friction and rotation, with the ſpherical lights of the ſmaller veſſels, put on a round figure.

§. 149. But the different natures of the ſeveral particles themſelves, which conjunctly make up the maſs of blood, are the cauſes whereby, from one and the ſame impetus of the heart, different effects or conſequences are produced in different particles of the blood. Namely, thoſe particles move quicker, whoſe greater denſity makes them receive a greater impetus, and whoſe apt figure or leſs extended ſurface makes them meet with leſs reſiſtance in the fluid, in which they move. Thoſe alſo are drove along more ſwiftly, which, either from their weight, or from the direction in which they paſs out from the heart, are urged chiefly into the axis of the veſſel. Thoſe again will ſtrike againſt the convexities of the flexures in the arteries, which have the greateſt projectile motion; while the other parts of greater bulk and tenacity, having leſs projectile motion, will move ſluggiſhly along the concavity of the veſſel. And, in this manner, is the blood prepared or diſpoſed for the ſeveral ſecretions.

§. 150. The ſyſtole of the arteries renders the parts of their contained fluids more denſe or compact, while they contract round the blood, as round a ſolid obſtacle, which being in ſome parts viſcid and compreſſible, they drive and expel the more liquid parts into the lateral mouths or ducts, at the ſame time increaſing the points of contact betwixt the globules themſelves, uniting together their more large and denſe ſpherules, and compacting the flat particles into denſer bodies. From this denſity, the redneſs of the blood ſeems chiefly to proceed; for that it is not merely the effect of the lungs, we are aſſured, from obſerving the ſame in fiſh, who have no lungs; but that the blood's redneſs follows from its increaſed denſity, we are aſſured from the philoſophical laws and optical experiments of Sir Iſaac Newton; and from experience itſelf, which ſhows us, that both the denſity and the redneſs of the blood are always increaſed together, by increaſing the exerciſe and motion of the muſcles, or even barely by accelerating the jet or ſtream of blood, that deſcends in a large arch from the vein into a veſſel.

§. 151. Moreover, the mouths of the leaſt veſſels, pervious to only one globule at a time, ſeem to be a ſort of moulds to figure and break off the angular eminencies of the particles in the blood, and bring them to a ſpherical figure, which, at length, they put on, and change into perfect ſpherules. Laſtly, from hence ariſes the denſity of thoſe particles, ſince of all figures, ſpheres contain the moſt, within a given ſurface.

§. 152. The *reticular* diſtributions and inoſculations of arteries § 37.) removes any danger of obſtruction, ſince, in any part of the artery, where the blood cohering, begins to form an obſtruction, a contrary flux is admitted, whereby the obſtructing matter is repelled to a larger part of the trunk, and thus, betwixt the reflux and the direct torrent of the blood, the ſaid matter is broke and attenuated. This mechaniſm alſo ſupplies the deficiency from an irremoveable obſtruction or the loſs of a veſſel, by cauſing a greater diſtention or enlargement of the next adjoining or anaſtomoſing veſſel; as is proved by experience in ſurgery, after tying and cutting a great artery.

§. 153. As the quicker motions of the blood in the trunks conduce to ſanguification, ſo the ſlower motions of it, in the leaſt veſſels, have their effects towards the ſecretions. In the larger arteries, we ſee the different particles of the blood are whirled about amongſt each other, with a rapid and confuſed motion; but, in the leſſer ramifications, the progreſſive motion of the blood being diminiſhed, the more looſe colourleſs particles depart laterally from the more denſe and red globules, while the latter, keeping on their courſe more firmly along the axis of the veſſel, expel the former laterally, and to the circumference. Thus the attractive powers of the particles in the blood increaſe, as their progreſſive motion abates; hence, the oily or fat particles are drawn one to another, and go off by the open lateral ducts, which lead to the cellular ſubſtance, which particles we know are both groſs and ſluggiſh: and again, other thinner juices are ſent off through lateral branches of a much ſmaller orifice, 'till, at length, little more than the red blood alone remains to paſs through the evaneſcent artery, into the incipient vein. But all theſe particulars, whereby the blood is diſpoſed for the ſecretions, we ſhall conſider more opportunely hereafter, in Lecture VIII.

REMARK.

Dr. Clifton Wintringham, in his experimental enquiry concerning the arteries and veins, has given us ſeveral obſervations worthy of notice; the principal of which are, That the veins are denſer in their membranes than the arteries: the aorta of a young man dead 48 hours weighed to water as 106 to 100, and the vena cava to water was 110 to

100. The thickneſs of the aorta was one ninth of an inch, but of the cava only $\frac{1}{154}$ of an inch; ſo the artery appears thicker than the vein as 17 to one. Thus the arteries being leſs denſe than the veins, are better adapted to continue the actions of life a longer time, without growing rigid and bony or cartilaginous, by the impulſe of the blood againſt their ſides: for had the arteries been originally as denſe as the veins, the animal could not have lived ſo long. For, by his ſecond propoſition, it appears experimentally, that the arteries are more denſe and rigid, as the animal grows older, whereby, when their reſiſtance equals the diſtractile force of the heart, they determine the ſize and growth of the perſon, (§. 252.). For in young perſons, the veſſels are obliged, by their conical figure, to yield more in length, than diameter, to the diſtending force of the heart; but when the firmneſs of the arterial coats can ſuſtain the impulſe of the blood, without an elongation of their fibres, the perſon grows no taller. As thoſe arteries, which ſpring neareſt from the aorta, have a greater ſhare of the heart's impulſe, they are therefore more denſe than their next collateral or ſmaller branches, which, being gradually more lax and eaſily diſtendible, is one cauſe of the blood's flowing ſo readily from the trunks into the arterial branches. Thus, generally, the fluids prevailing over the ſolids for the firſt 20 years, the perſon will be ſo long growing; and then, for 20 years more, the perſon will be nearly at a ſtand, from the equilibrium of the ſolids and fluids, which now admit only a lateral diſtention, by which the perſon grows not in height, but increaſes in bulk (which is not properly growth, as it ſprings not from any ſolid concrement, but an accumulation of fat and juices, that was formerly ſpent in growth); and then, for 20 years more, the ſolids, by repeated action, being grown

too denſe, the equilibrium turns on their ſide, the fat and juices, formerly collected, are now conſumed and expelled by the greater power of the veſſels; and, as we ſee from experiments, the ſmaller veſſels, concreting into ſolid fibres, make the arterial coats much thicker and tougher in old, than young ſubjects: in conſequence of this, the force, to excite any degree of motion in young animals, muſt be increaſed to produce an equal effect on the fibres and veſſels of an old one. Hence we ſee a greater influx of ſpirits is neceſſary to actuate the organs of an old perſon, which yet cannot be now ſecreted by a brain more callous and impervious, from a blood leſſened in its proportion, ill-circulated and ill-formed by a weakneſs and inactivity, now obtaining in both the ſanguificative and chylificative organs, &c. Hence a ceaſing of the fecundity and menſes in women, a collapſed or ſhrivelled habit in old men, univerſal torpor, tremors, &c. And theſe experiments alſo furniſh one reaſon, why conſumptions, from a rupture of the pulmonary veſſels, ſeldom happen before the age of 20 or after 40; becauſe, in the firſt ſtage, the redundance of juices is employed in the growth; and, in the laſt, the over denſe fibres and veſſels do not ſo eaſily break or yield to the impelled fluids.——An inch of the aorta from a young man burſt with the force of 131 pounds, 10 ounces. The aorta of males is near a fifth part denſer and tougher than in females; but the veins, as in the cava, only a ſixth or ſeventh part. But even the aorta is leſs denſe, or more eaſily dilatable near the heart, than its branches. So by experiments, we ſee it is a juſt obſervation of Dr. Pitcairn and Friend, that the inferior ſeries of veſſels are proportionably more capacious (a fifth or ſixth part) in females than males, and in compariſon with the upper ſeries of veſſels; whence a greater flow of blood for the fœtus and menſes. But the veins in females are ſmaller, ſo that the blood moves faſter in a woman's veins, and ſlower in her arteries, whereby its fluidity is better maintained, and its texture leſs vitiated by the numerous obſtructions that attend geſtation.— The extrordinary capacity of the cava above the emulgents, beyond that of the aorta, being nearly as two and an half to one, makes it of ſingular ſervice as a reſervoir to collect the blood, or ſupply the heart in weakneſs, and prevent a ſurcharge in running, ſtraining, fullneſs, fevers, &c.——Anatomiſts have erroneouſly ſuppoſed the ſtrength of arteries and veins to decreaſe in proportion, as they grow leſs in thickneſs; for, by experiments, it appears the thinneſt veſſels have often a much greater degree of compactneſs and ſtrength, proportionably than the larger; and ſome whoſe coats are extremely thin, exceed in ſtrength the aorta, whoſe coats are ten times as thick. The emulgent artery was found a fifth or ſixth part ſtronger than the aorta at the heart; and the emulgent vein was two thirds ſtronger than the cava. The porta was ſtronger than the ſplenic vein nearly as 5187 to 1000. The ſplenic artery was ſtronger than the iliac nearly as 148 to 100; but the iliac vein was ſtronger than the ſplenic as 35 to 10 nearly; and the emulgent artery was ſtronger than the iliac artery as 1376 to 1000. In a word, the arteries are infinitely diverſified as to their ſtrength and capacity, obſerving no regular proportion; whence it is abſolutely impracticable to account for the ſecretions thence.——The veſſels of the pericranium, dura mater, pleura, and all denſe membranes, eſpecially thoſe attached to bones, ſhall have a violent degree of pain from a diſtention, that will not affect other veſſels; becauſe the former, yielding in points leaſt reſiſted, will not dilate in a ſphere, but an ellipſis or a leſs figure; whence the reaction of the reſiſting parts will be turned upon thoſe that yield, whereby the diſtraction and pain will be double, if only half the veſſel can dilate. Hence we ſee, why pain may be in ſome veſſels and not in others, coming from the ſame trunk, and urged by the ſame diſtending cauſe: and why pain is more violent in ſtrict, tenſe habits, than where the the fibres are lax, &c.

LECTURE VII.

Of the nature of the blood and juices of the human body.

§. 154. THE very complex liquor, which is contained in the beating arteries and their correſponding veins, is called, by one general name, the *blood*, which, to a looſe examination, appears homogeneous, or of ſimilar parts, red and coagulating throughout. But experiments of divers kinds have ſhown us, that diſſimilar parts of various natures reſide in the compoſition of this animal liquor.

§. 155. Hydroſtatical experiments demonſtrate in the blood firſt a kind of volatile vapour or exhalation, which immediately and continually flies off from the warm juice, with a ſort of fœtid odour coming betwixt that of the ſweat and urine. This vapour, being catched and condenſed in proper veſſels, appears of a watry nature, joined with a ſmall tincture of an alcaline diſpoſition.

REMARK.

This halitus of the blood conſiſts of an ammoniacal ſalt, ſo attenuated as to be volatile, without altering its nature much to the alcaline claſs; which, joined with a ſmall portion of oil and much water, affords that remarkable nidorous ſmell upon opening a dog, hog, or other carnivorous animal, whilſt warm; for in oxen, ſheep, calves, &c. feeding on graſs or grain, it has ſcarce any perceptible ſmell; but in mankind, it has a very particular odour, flying off chiefly in the perſpiration, by the ſcent of which, every dog can diſtinguiſh and follow the foot-ſteps of his maſter.

§. 156. After this vapour is gone off, the blood of a healthy perſon ſpontaneouſly congeals into a ſciſſile trembling maſs; and with a leſs degree of heat than that of boiling water, (viz. 150 gr. i. e. 62 leſs than boiling water) it grows more tough, like to a boiled egg. But even within the veſſels of a living perſon, dying of a fever, the blood has been ſeen by the violence of that diſtemper, changed into a concreted tremulous jelly throughout all the veins. The principal part of this coagulated maſs, is the *craſſamentum* or *cruor*, which has the red colour peculiar to itſelf, and gives it to the other parts of the blood. This, if it be not kept fluid by the attrition of a vital circulation, or ſome ſimilar concuſſion, runs confuſedly into a compact, but ſoft maſs, merely by reſt and a moderate degree of cold, as it alſo does by the addition of alcohol, by mineral acids, or by a heat of 150 degrees, [of which 98 is the blood's heat in robuſt people; 175 boil alcohol vini; 190 boil proof brandy; and 212 boil ſpring water.] 'Tis either as a fluid or a ſolid ſpecifically heavy, and more ſo than water, by near an eleventh part; and when freed from its water, it is wholly inflammable. In a maſs of healthy blood, one half or upwards is red cruor; and in ſtrong laborious people, the ſerum makes only a third part, and is ſtill more diminiſhed in fevers, often to a fourth or fifth part of the maſs.

§. 157. Next to this comes the white or clear and the yellowiſh part of the blood, which again ſeems to be a liquor, conſiſting of homogeneous or ſimilar parts, when it is not really ſo. This *ſerum* (as it is called) of the blood is, in general, one thirty eighth part heavier than water, and almoſt a twelfth part lighter than the red globular maſs of craſſamentum: this too, by an heat of 150 gr. or by mixture of mineral acids or alcohol, and by a concuſſive motion is congealable into a much harder coagulum than the red cruor (§. 156.), or mixed maſs (§. 154.); and forms an undiſſolvable glue, a fleſh-like membrane, which, at length, ſhrinks up to a horn-like ſubſtance. From thence are formed the pleuritic cruſt or ſkins, polypuſſes and artificial membranes. In this ſerum of the blood, beſides the albumen, which will harden like the white of an egg, there is concealed a great deal of ſimple *water*, which even makes the bigger part of the whole, and ſome quantity of a ropy *mucus*, drawing out into long filaments, like ſpiders threads; which laſt, however, is not coagulable like the albumen, neither by fire nor by acids.

§. 158. But by putrefaction only, or the diſſolving power of the air hot to 96 gr. equal to the blood's natural heat, the whole maſs, but eſpecially the ſerum, diſſolves or melts into a fœtid liquor, firſt the ſerum, and then the cruor more ſlowly; till, at length, the whole maſs, both of ſerum and cruor, are turned into a volatile and fœtid exhalation, leaving very few fœces behind. When the blood has been once diſſolved by putrefaction, there is no artifice can harden or congeal it; as there is none likewiſe that can reſolve it again, after it has been once coagulated by ſpirits of wine. [The natural gelatinous denſity and coheſion of the blood is diſſolved in malignant and contagious fevers.]

§. 159. Beſides theſe parts of which the blood appears to conſiſt, without ſubjecting it to any violence, it contains in its ſubſtance a quantity of *ſea-ſalt*, which is diſcernable to the taſte, and ſometimes viſible by the microſcope. The fine chalky *earth*, lodged in the blood, is demonſtrated from its affording the matter of nutrition and from a chemical analyſis, whereby it appears to lodge in the moſt fluid parts of it, and is more eſpecially intimately combined in great plenty in the oily parts of the blood. Another part in the blood is *air** in an unelaſtic ſtate, and that in a very conſiderable quantity; [*to the weight of half a ſcruple in an ounce*] the exiſtence of which air, in the blood and ſerum, is proved by their putrefaction and diſtillation, or by removing the ambient air from them by the pump. But we are not to think from hence, that the blood-globules are bubbles full of air, for they are ſpecifically heavier than the ſerum, and make no dilatation, by taking off the preſſure of the atmoſphere from them by the pump. [Laſtly, it appears from late experiments, that the caput mortuum or aſhes of the blood are repleat, with a ſort of iron, which the load-ſtone will attract; and which being found alſo in the aſhes of vegetables, as well as animals, and in moſt earthy bodies, is, therefore, by ſome, reckoned an element or conſtituent principle of bodies.]

REMARK.

* The air, as a fixed element in the compoſition of ſolid and fluid bodies, has been generally overlooked by philoſophers, and even by the chemiſts, who have, above all ſects, gloried in their knowledge of principles or elements; until Mr. Boyle, Sir I. Newton, and more eſpecially Dr. Hales, by many curious and uſeful experiments, demonſtrated, that a great part of the ſubſtance of moſt bodies, in ſeveral to half their weight, is a permanent or unelaſtic air, which being freed [either (1.) *ſlowly*, by the air-pump, putrefaction, fermentation, diſtillation, &c. or (2.) *ſuddenly*, by exploſions, fulminations, ebullitions, mixtures, &c.] from the other ſolid particles, aſſumes its elaſticity, and fills an immenſe ſpace, in compariſon of the body from whence it came. Among other experiments, Dr. Hales found a cubic inch of blood, in diſtillation, afforded above 30 times its bulk of elaſtic air; whoſe particles are, in effect, the wedges of nature, which, depoſing their elaſticity, pin and cement together the other elements (V. remark ad §. 2.) and particles of bodies for their growth or accretion; and, under other circumſtances, regaining their elaſticity, ſerve to break and repel again thoſe parts for the deſtruction or diſſolution of the compound, whoſe matter may be, by the ſame inſtrument, again differently aſſembled and combined for the forming of other bodies. In general, the nitre contains moſt air among the foſſil ſalts, which being ſet ſuddenly at liberty, by exploſion, gives the force of gunpowder; among vegetables,

getables, tartar is half its weight air, above eight gallons in an ounce; and the ſame proportion of air is there in human calculi, from the gout, kidneys, or gall bladder; next to theſe, the bones have moſt, the ſolids more than the fluids, the craſſamentum than the ſerum, &c. See more of this in the vegetable and hæmaſtatics of Dr. Hales, which, for their copious, new, curious and uſeful matter, deſerve a place in every Phyſician's library. Some poiſons diſpoſe the permanent air-particles to turn elaſtic, and ſeparate from the animal juices, with which they are incorporated; whence a wonderful turgeſcence of the cellular ſubſtance and ſmall veſſels throughout certain parts, or through the whole habit. And hence, from the ſtagnant and putreſcent juices, may ariſe emphyſematous tumours, and a tympany of the abdomen; how much ſoever, ſome ſurgeons may ridicule the notion and name of thoſe diſtempers. There is, without doubt, a circulation of fixed air, abſorbed by the inhaling veſſels of the lungs, alimentary tube, and ſkin; and the lungs probably exhale again ſuch particles, as regain their elaſticity in the blood. For that there often are ſuch elaſtic parts of air in the blood, eſpecially after drinking flatulent wines, cyder, &c. I am very certain, from the colliſion and rattling I have often heard them make in the auricles or ventricles of my heart; which I frequently humoured and varied by different geſtures of the thorax, and degrees of reſpiration; and I know not what could become of this air, unleſs it eſcaped by the lungs, or was abſorbed again as a ſolid by the blood.

§. 160. Among other bodies, chemiſtry has various ways endeavoured to ſhow us the nature and principles of the blood; which being freſh drawn, and diſtilled with a ſlow heat, [gr. 212, or below boiling water] yields a *water* to the quantity of five parts in ſix of the whole maſs; which water has little or no taſte or ſmell, 'till you come towards the end of the operation, when it is proportionably more charged with a fœtid oil, as it draws nearer to a concluſion. (2.) What remains after you have drawn off this water, being expoſed to a ſtronger fire, yields various alcaline liquors; of which the firſt being acrid, fœtid, and of a reddiſh colour, is uſually called the *ſpirit* of blood; conſiſting of a volatile ſalt, with ſome little oil, diſſolved in water, to the amount of one fiftieth part of the whole original maſs of blood. (3) A little before and together with the oil, that next aſcends in the diſtillation, a dry *volatile ſalt* ariſes and adheres in branchy fleeces to the neck and ſides of the glaſs; and this in but a ſmall proportion, leſs than an eightieth part of the firſt maſs. (4.) The next liquor is that called *oil* of human blood, which aſcends gradually thicker and heavier, at firſt yellow, and afterwards darker to a black, 'till, at laſt, it reſembles pitch; being very acrid and inflammable, but in a ſmall quantity, about a fiftieth of the whole maſs. (5.) What now remains of the blood, in the bottom of the retort, is a ſpongy inflammable coal or cinder, which being kindled burns away, and leaves aſhes behind; which, being diſſolved into a lixivium with water, affords a *mixed-ſalt*, partly ſea-ſalt and partly fixed-alcaly, leaving a mere dead *earth* in the filter. This fixed ſalt is ſcarce the five hundredth part of the firſt maſs, and has in itſelf only one fourth part alcaline: but being urged with the moſt intenſe degrees of fire, the whole ſalt affords ſome portion of *an acid ſpirit*; which we judge to ariſe partly from the ſea-ſalt in the blood, ſome of which is demonſtrable even in the ſpirit of blood, and partly from the vegetable kind of the aliments, not yet digeſted into an animal nature. For which laſt reaſon, an acid is procurable from the blood of graminivorous animals, as well as from that of man. But the *earth*, ſeparated from the lixivium by filtration, will, perhaps, make about one hundred and fiftieth part of the original maſs; and contains ſome particles which are attracted by the load-ſtone. The ſerum only of the blood, by diſtillation, alſo affords altogether the ſame principles; only the water is more abundant, as the oil and earth are in a leſs proportion.

REMARK.

Add to theſe, another very conſiderable principle of the blood, even three times the weight of the earth it contains, and, when ſeparated, near 40 times the bulk of the whole maſs, [to which add, the elementary æther or fire, §. 2.*] viz. the permanent air, which, as we before obſerved, (remark to §. 159.) is uſually overlooked, becauſe it ariſes inviſibly in the diſtillation; though, if the veſſels are too cloſe luted, or the fire urged too briſkly, it will generally make the operator hear, at leaſt, if not feel it, by burſting his glaſſes. Obſerve again, that theſe are not the natural, but factitious principles of the blood, i. e. to ſay, they have neither the ſame forms, nor the ſame properties, when they are combined together to make blood, as they appear to acquire by an artful ſeparation. We can only ſay, that ſuch a number and proportion of the more ſimple or elementary ſubſtances of the univerſe, concur to make the natural elements of the blood, i. e. ſuch as the mechaniſm of the human body itſelf forms of the ingeſted aliments, which are only two, viz. albumen and globules, viz. one an unorganiſed, colourleſs, inodorous, and inſipid jelly, like the white of an egg, ſomewhat ropy or filamentary, in proportion to the celerity of the circulation, and differing in tenuity, as it paſſes through leſſer orders of veſſels. This makes the immediate matter of growth and nutrition, by ſticking to the ſides of the leaſt fibres, when it is poured in betwixt them by the leaſt veſſels, while the elaſtic organiſed globules of the leaſt or ſmalleſt claſs, which make the organic part of the nervous juice, from their greater ſuſceptibility of motion, moſt likely re-enter the cells or other pores that can ſend them again into the common circulation. There are then as many kinds or degrees of tenuity in the nutritious albumen of the blood, as there are orders of globules, and ſmaller veſſels to paſs through, before the firſt can adhere as nouriſhment to the leaſt fibres. The organiſed or elaſtic elements of the blood are then neceſſary in a certain proportion to grind and prepare the other albumen; and are, therefore, to be eſteemed a ſolid permanent part of the body, ſince they never paſs the emunctories, but by exceſs or diſeaſe. As for the ſaline, acid, morbid, bilious, &c. particles, to be found mixed in the current blood, theſe are rather heterogeneous than elementary parts of it, and reſtrained to the ſecretory veſſels only, which ſend them off to make the excretions and certain few ſecretions.——As to the particles attracted by the load-ſtone from the earth of the blood, which may ſeem ſo ſtrange to ſome, 'tis obſervable, that Sir Theodore Mayern and Dr. Liſter found, that many ſuch particles were always lodged in human calculi, and might be alſo extracted from the aſhes or earthy parts of moſt plants; whence ſome have thought the minera of iron a kind of univerſal element or principle of mixt and text bodies, and, I think, not very injudiciouſly, ſince they are more or leſs diffuſed through the whole earth and waters, and never touch any ſalt of what kind ſoever, but intimately join with them into a vitriol, which is more or leſs in all ſprings whatever; and it is notorious, that yellow brewer's-clay, loom, ſands, &c. are all tinctured by iron; what wonder then if it aſcends with the ſalts of the earth into vegetables, and with them paſſes into animals, in both which, its particles ſhall be intrinſically, from their own nature, ſome of the firſt that lay the baſis of accretions, whether natural or morbid, in animal or vegetable bodies.

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* V. Remark to §. 2, number 2. which never loſing its elaſticity, as does the air, is the firſt and great univerſal agent that actuates the reſt of the elements for varying the face of nature.

§. 161. From the preceding analyſis of the blood, it evidently contains a variety of particles, differing in bulk, weight, figure, and tenacity; ſome watry, others inflammable, and moſt of them inclined greatly to putrefaction, or to an alcaline corroding ſtate. For the blood, in a ſound healthy ſtate, not injured by putrefaction, or too violent a degree of heat, is neither alcaline nor acid, but mild or gelatinous, and a little ſaltiſh to the taſte; yet, in ſome diſeaſes, it is ſharp enough, and comes near to a ſtate of putrefaction; as for inſtance, in the ſcurvy, where it corrodes through its containing veſſels, and in thoſe who have an aſcites or dropſy, whoſe waters are often much of an alcaline and corroding nature. But that which is as blood in inſects, affords a ſharp alcaline calx, effervеſcing with acids. If human blood be mixed with alcohol or ſtrong mineral acids it runs into a coagulum; but, by the milder vegetable acids, verjuice, vinegar, lime-juice, &c. and alſo by alcaline ſalts, fixed or volatile, but eſpecially the laſt, and by nitre or all neutral ſalts, it continues or even re-aſſumes its firſt fluidity. There is no ſalt with which the blood makes any efferveſcence. Violent exerciſe, too long continued with too great external heat, ſoon diſſolve the blood into a putrid ſtate even within the veſſels of a living perſon.

REMARK.

We ſee hence, that too much or too little motion of the blood will, either of them, cauſe a morbid acrimony, the firſt in a little time as in fevers; and the laſt in a longer time, as in cachexies, ſcurvies, &c. In the fevers, which begin without any diſſolving contagion, as well as in too much or long continued hard labour, the blood runs on from the beginning toward the height, through various degrees of inflammatory tenacity, i. e. to ſay, the more thin and aqueous parts being gradually more thrown out by the fluid ſecretions, the nutritious albumen or glue in the blood, which forms a ſort of cruſt round the ſurface of each globule, becomes ſo thick and tenacious, that they join more ſtrongly together into coheſions, unleſs kept aſunder by motion; but the ſame degree of motion or impetus will make thoſe globules keep changing their points of contact longer, which have the greater denſity, i. e. the red ones; conſequently the ſmaller pellucid globules will, in this caſe, from their leſs motive power, and from their greater ſurface, which augment the attraction of coheſion, firſt run into filamentary concatinations; for when the attraction of coheſion is increaſed to a certain degree, their ſpherical figure will, in all points of contact, be depreſſed like flattened cakes, and that more or leſs in various degrees, proportionably to the fewer ſaline, watry, &c. particles, which interpoſe and prevent their cloſeſt coheſion. This will account both for the production, increaſe, and degrees of toughneſs in the pleuritic inflammatory cruſt of the blood, which is ever an attendant, more or leſs, upon an accelerated circulation through the whole ſyſtem, or only ſome particular part, from pain particularly, provided there is, at the ſame time, no ſaline, putrid or diſſolving acrimony in the maſs. If the arm of a perſon, who has healthy blood, and no ſhow of this cruſt, be tied up for ſome few (10 or 20) minutes, a ſort of temporary, but little painful inflammation is produced in that part; the aqueous and the thinner juices are urged into the cellular ſubſtance and ſmaller veſſels from the red blood, whence a turgeſcence of the limb below the ligature, by which the blood, in a degree, confined and ſtagnant in the veins, will have ſome of thoſe parts tending to concretion, which retain the leaſt impulſe or motion, namely, the pellucid larger ſurfaced globules, now from ſtagnating, more thickly incruſted with the coheſive glue; whence, upon extravaſation into a cold veſſel, they ſhall be the firſt that run into coheſion (not with the red globules, for theſe, having leſs ſurface in proportion to their matter, have leſs coheſion, but) with ſimilar particles, ſo as to form a white cruſt, proportionable to the tenſity of the ligature, and length of time the arm was bound up, provided the vein was opened with a large free orifice; for this ſeparation or ſortment of ſimilar cohering parts is begun in the vein, and lodged, as it were, in ſeveral circular ſtrata, moſt next the coats of the veſſel, and is then, at length, compleated, when let out into the veſſel; but a ſmall orifice, as it lets out only the quicker-moving central thread of the cylinder of blood in the vein, conſiſting of the redder denſer particles, will give little of this cruſt, and of courſe but little relieve the pain; which it occaſions, by lining the ſides of the leaſt arteries with too thick an incruſtation; whence they will be fuller, tenſer and harder, and of courſe more painful. Hence we ſee the uſe and action of nitre, neutrals, ſalts, vegetable acids, and volatile alcalines well diluted, towards removing this phlogiſton of the blood; which, we ſee, is no longer to be found, when the coheſive glue or albumen begins to diſſolve by a return of putrid bile or a putrid alcaleſcent ſtate of the juices in general, brought on by the length and intenſity of the fever. You may, in like manner, account for its appearance, when the veſſels are obſtructed in women with child, as from the ligature above. As this phlogiſton lies moſt in the leaſt arteries, and thoſe veins in which the blood moves ſloweſt; therefore, we ſee how cupping, by diſcharging more of it, relieves the pain better than bleeding from a large vein, in which the blood moving faſter contains proportionably leſs of the ſaid inflammatory lentor. Alſo, why bleeding from a large orifice relieves more than from a ſmall one. How a bliſter, by the alcaline diſſolving force of the calx in the blood of the Spaniſh and other ſcarab flies, is ſo uſeful to thin, diſſolve, abſterge, and ſhake off this lentor from the ſides of the leaſt veſſels, where it moſt heſitates:

for a bliſter is often of uſe, by thoſe parts of it which enter the blood and diſſolve the juices; when its action, as a ſtimulus upon the ſolids, is rather miſchievous; and hence bleeding, diluting, clyſters, &c. are moſt neceſſary companious of it, while, at the ſame time, that the juices may be ſupplied with the virtue of the flies, the firſt bliſters muſt be either dreſſed with an ointment of them, or a ſucceſſion of new bliſters to other parts be made. But in pleuriſies, and other pains from a cold, acid, and ropy viſcidity in the leaſt veſſels, quite oppoſite to the phlogiſton, bliſters have alſo a double advantage; ſince there a briſk degree of fever and ſtimulation of the ſolids, as well as a diſſolution of the viſcid lentor, is required. Therefore, in all fevers, where the blood does not tend to a colliquation of its glue and globules, from contagion, bile, pus, or an alcaleſcent putrefaction, a timely uſe of bliſters and cupping to proper parts will ever turn to good account; if where the pulſe is hard, and the blood buff, you bleed and dilute well with nitre and acids; and if with a ſoft pulſe and poor watry blood, you give the bark with nervous and diaphoretic (viz. Julep. Camph. Tinc. Caſtor. Valer. &c.) medicines after firſt clearing the paſſages by a moderate doſe of rhab. alone, or with calom. &c. Another advantage will attend an early uſe of bliſters to the feet, as a revulſive of the phlogiſton, and of the cold viſcid lentor likewiſe from the pneumatic and ſanguificative viſcera, no leſs than as an attenuater of it; whenever you perceive it begin to ſettle in thoſe organs, where it excites, agreeable to the nature and uſe of the organ, and degree of its accumulation, thoſe moſt numerous and troubleſome ſymptoms, by which, without much altering their eſſence or cure, fevers are largely diverſified. 'Tis then evident, (1.) That in all true fevers there is ſome matter to be prepared and expelled from the blood by nature, or the conjunct powers of the nervous and vaſcular ſyſtem. (2.) That this matter is either a *cold*, viſcid, acidiſh, ropy, and crude matter, as in intermitting, leuco-phlegmatic, ſlow, nervous, and moſt hyſterical or hip fevers; of which, the fever itſelf, with bliſters, the bark, and nervous corroborants are the cure: or it is of the pleuritic inflammatory kind, which, as a phlogiſton, having once taken up its ſeat in the ſmaller arteries and veins of ſome part, multiplies itſelf, and increaſes or continues the fever, 'till its action has introduced ſuch a ſaponaceous, diſſolving, or alcaleſcent ſtate throughout the juices, as, at length, melts and expels the phlogiſtic lentor itſelf; which then, like a well concocted matter, runs off critically by ſome emunctory. Here, to prevent the colliquation from extending beyond the lentor, even into the firmer globules of the blood itſelf, ſmall, and often repeated, doſes of the vitriolic acids, alum and the bark, have a moſt certain, and almoſt miraculous, effect in cauſing a precipitation of the now ſubdued matter by the renal, inteſtinal or cutaneous outlets, and in reſtoring the lately overſtrained veſſels immediately to their due action and effects upon the contained fluids. To which practice, I was lead (having the rationale of the thing, and the practice of Dr. Morton on my ſide) with the moſt ſurpriſing ſucceſs, wherever it was ordered; and I have now the pleaſure of ſeeing the ſame practice almoſt as ſtrongly recommended by Dr. Huxom, from his own ample experience. Only two things you muſt have a regard to; namely, (1.) To ſee that your lentor is fully ſubdued, or that this colliquative ſtate of a fever be actually begun, as you will know by the ceſſation of pain, ſoftening of the pulſe, length and degree of the fever that has preceded, &c. as well as from the appearance of the blood itſelf, which ſhould now be drawn in no greater quantity than will ſuffice to give us a view of its ſtate. (2.) That your patient have no icteritious or bilious appearance, denoting, that though the lentor be ſubdued in the other veſſels, yet a part of it ſtill lurks, in a manner, almoſt out of the high road of circulation, in the ſlow moving veſſels and juices of the liver; for here our good medicine will, by coagulating and fixing the lentor, either cauſe a new fever, or ſuch an inſuperable obſtruction, as muſt pave the way to an hundred chronical diſtempers, which are too frequently to be met with in perſons not judiciouſly cured of fevers.——Even in the third and laſt kind of febrile matter, which is generally contagious, epidemical or eruptive, a moderate uſe of the ſame medicine, to guard the texture of the blood and ſmaller veſſels from the diſſolving force of the febrile poiſon, in the height and declenſion of the diſtemper, will be of great uſe; if you remember at the ſame time, that this matter, not being ſuperable, like the former, by nature (the characteriſtic of a poiſon) muſt be expelled with a moderate uſe of the mild diaphoretics.

§. 162. Laſtly, by viewing freſh blood in a ſmall glaſs tube by a microſcope, or by inſpecting it with the ſame optical inſtrument, while it is yet moving in the veins of the living animal, we diſtinguiſh its ſoft, red globules, which are elaſtic, ſo as to be able to change and recover their figure, and which, doubtleſs, make that part called cruor or craſſamentum of the blood, mentioned at §. 156. [If it be queſtioned, whether theſe are not rather oleaginous lenticular particles, of the ſame kind with thoſe obſerved by Lewenhoeck in fiſh, and lately diſcovered in our own ſpecies? we confeſs it is a point difficult to determine; but the ready and frequent diviſion of oil or fat into globules by concuſſion ſeems to countenance ſuch an opinion.]

§. 163. Thoſe red globules (§. 162.) we ſee ſwimming in a thinner liquor, in which, by the ſame microſcope, we alſo diſtinguiſh leſſer yellow globules; and obſerve, that the red ones diſſolve into ſimilar yellow or ſmaller globules, by reſt and warmth. The diameter of the red globules is, by the moſt accurate experimentors in this way, computed at $\frac{1}{3240}$ of an inch.

§. 164. The pellucid water remaining, in which the former globules were obſerved to ſwim, does yet, by the finer microſcopes, appear to contain ſtill ſmaller globules of an aqueous clearneſs, with various ſpicula of ſalts.

REMARK.

The diſcovery and conſideration of this mechaniſm of blood, whereby we ſee it, in great part, conſiſts of elaſtic, organic, round machinulæ of various denſities and diameters, which, by their greater mobility from one common impulſe, grind and attenuate the other viſcid nutritious and filamentary or ropy parts of the blood, is of the laſt importance towards underſtanding the nature, action, and cure of fevers, poiſons, and moſt diſorders ſpringing principally from a vitiated ſtate of this general ſource, from which all the other animal juices are ſupplied. We obſerve, that ſugar boiling in a ſyrup at the bakers, in ſome meaſure reſembles the blood, as a ſoft or ſolid body, (remark to §. 1.) kept by the violence in a ſtate of fluidity. This, when its watry parts are exhaled enough to give the ſugar ſo great a heat as to extricate and expel part of the included permanent air in the ſhape of elaſtic veſicles or bubbles, (remark to §. 159.) it ſwells to ſuch a degree from the ſaid air confined by the tenacity or coheſion of its parts, that the whole would ſoon be thrown out of the copper, if it were left to itſelf. But to prevent this, a ſpoonful of butter or oil thrown in, diffuſes itſelf ſo throughout the whole maſs, that, by leſſening the contact and coheſion of the particles, the confined air readily eſcapes as from water, and the ſwelling or turgeſcence immediately ſubſides. Much in the ſame manner, certain vegetable, animal and contagious poiſons ſhall, upon entering the maſs of blood, diffuſe and diſſolve that healthy degree of coheſion in the parts which is neceſſary to make and keep it an organic fluid, that it ſhall, in a little time, turn from a mild albuminous to a corroding gangrænous incoherent maſs, diſſolving not only the globular texture, but alſo the pulpy fine vaſcular fabric in the encephalon, almoſt as ſoon as it can extend thither. Thus, among the vegetable tribe, act the laurel-water, circuta-aquatica, the great purple-flowered wolf's-bane, deadly-night ſhade, hen-bane, nux vomica, roots of hemlock-drop wort, (and even opium itſelf in a large doſe); only, as theſe are commonly taken into the ſtomach, they begin the tragedy firſt in that part, which, from its ſenſibility and nervous conſent, excites many ſymptoms not ſeen in other poiſons. Thus act the epidemical, contagious and peſtilential poiſons, with thoſe of the ſnake kind. In how few hours the peſtilential poiſon will often kill, and melt not only the blood, but even the liver, ſpleen, lungs, and other viſcera into a gangrænous incoherent maſs, thoſe are not ignorant, who have read the writers on the plague. And how ſoon the rattle-ſnake poiſon will have the ſame effect, may appear from the late creditable relation, which father Feuill gives us in his journal of phyſico-mathematical obſervations made in New Spain, of a Dutch phyſician at Lima, who being herbalizing in a wood, and hearing a young Indian woman cry out from the bite of a rattle-ſnake, immediately ran to her aſſiſtance; but well knowing the fatality of the poiſon, ſent one to call the pariſh-prieſt to give her confeſſion and communion; but before he could arrive ſhe died, and changed ſo much in a few hours, that, in lifting her body, the fleſh, like a pulp, came off as if it had been corrupted, which obliged them to put the body in a cloth to carry it to the church. What a colliquative ſtrength the leaſt quantity of this poiſon has, may be ſeen from the terrible courſe Mr. Briental went through at Philadelphia, (Phil. tranſ. n°. 478.) who, by the precaution of ſucking his wound and ſpitting out the poiſon, (which benumbed his tongue and lips) making a ligature to confine what remained in the arm, and a copious diſcharge by ſcarifying his hand, and ſlitting the ſkin of his fingers, was lucky enough to eſcape with life, after lying ill nine days; though the hand and arm continued all the ſummer ſpotted like the ſnake. Nor is the gangrænous diſſolution and acrimony, which the blood often acquires by ſlow degrees in the ſcurvy, much leſs wonderful; by which, in the account of Lord Anſon's voyage, it melted and eat through the tough calluſſes of bones and hard ſcars of old wounds, ſo as to make them bleed afreſh. But let us return from the diſeaſed, to the natural and healthy ſtate of the blood.

§. 165. From the preceding experiments compared together, ariſes that knowledge which we, at preſent, have of the blood; namely, that the craſſamentum or cruor is compoſed of globules, which being forced together by the coagulating cauſes, (§. 156.) which increaſe their attraction of coheſion, harden into a confuſed ſolid maſs. The inflammable or combuſtible nature of the ſaid globules is proved from dried blood, which takes flame and burns; as alſo from the phoſphorus, or rather pyrophorus, (ſince it not only ſhines, but generates combuſtible fire) which is diſtilled from human blood; and from theſe probably ariſes the greater part of the pitchy oil that is obtained from blood by the violence of fire, §. 160. (4.) But actual filaments, there are none naturally in the blood; though they may be made in it, by the addition of cold water.

REMARK.

The attraction of coheſion in particles being as their contiguous ſurfaces and tenacity of the incruſting fluid, the yellow and leſſer globules will cohere together more powerfully than the red ones, as well from their greater ſurface and contacts, as becauſe moving ſlower in the blood, a more viſcid and thick glue adheres to them; whence by cold or intenſe heat, or a diminution of the interpoſed water, theſe firſt run into ſtrong filamentary chains every way, like a ſponge made of ſpider's threads, betwixt which the larger red globules are locked up or intercepted; and by waſhing them out with water, from a cake of freſh ſound blood, you have the filamentary part compacted together like a fibrous fleſh. And as theſe leſs globules thus more ſtrongly attract each other, than they are attracted, either by water or by the red globules; therefore, upon ſtirring round a maſs of blood with your finger, &c. before it is congealed, inſtead of ſhooting every way like the threads of a ſponge through the whole maſs, ſo as to give it a kind of ſolidity, they will be wound up into a bottom of a compact fibrous conſiſtence, leaving the remainder a purple uncongealing fluid, chiefly of water and the red globules, &c. Much in the ſame manner, we ſee in chemiſtry, that ſpiritus ſalis ammoniaci (cum ſale tartori preparatus, which is ſtill no more than a ſalt diſſolved in water) & alcohol vini being mixed, the ſalt immediately ſhoots every way like a lump of ſugar, while the water and alcohol combined, are locked up in the cells or interſtices.

§. 166. The yellow ſerum of the blood appears likewiſe to conſiſt of leſſer globules ſwimming in water; and is what we deſcribed before at §. 157. In the watry or thinner liquor of the ſerum, whoſe particles are not viſible to the eye, there are contained the ſame principles, with a portion of water, as was ſhown in the blood itſelf, §. 160. of which the force of fire makes alcaline ſalts. In proof of this, we may alledge a diſtillation of the ſaliva or mucus with the nature of the perſpiring matter of Sanctorius.

REMARK.

The ſaline and oily parts of the ſerum, as well as the blood, are in a healthy ſtate, neither acid nor alcaline, but neutral, of a peculiar kind, coming betwixt nitre, ſea ſalt and ſal ammoniac; whence healthy ſerum, though brackiſh to the taſte, gives no pain to a wound, to the eyes, noſe, or to other ſenſative organs, where even water alone will prove a ſtimulus: but thoſe few volatile alcaline ſalts and oils, which come into the blood from the aliments or medicines, or which are made by the vital heat and attrition, exhale chiefly by the perſpiration; which obſtructed, cauſes a retention of that matter, which, if retained in a conſiderable degree, will ſtimulate the heart and arteries into a fever, and tend to diſſolve the blood into a putrid maſs, if left to itſelf. The ſame perſpirable oily and ſaline parts, in a more exalted, putrid, and cauſtic ſtate, of which it is capable of various degrees, becomes the matter which propagates contagious fevers of all kinds; being in itſelf an animal ferment, that diſpoſes the airy, oily, and ſaline parts of the blood to ſeparate by a putrefactive or inteſtine motion in the leaſt veſſels, where the progreſſive motion is ſloweſt, ſo as to put on an acrid diſpoſition ſimilar to that of itſelf: but the chemical volatile ſalts and oils of blood and ſerum, as well as of other animal ſubſtances, are not the natural, but factitious principles of them made by force of fire.

§. 167. The exact maſs or quantity of blood, contained in the whole body, cannot be certainly computed. Yet we know, in general, that the maſs of humours is much greater than that of the ſolids; only we are to conſider, that many of them do not flow currently in the circulation, as the glue or jelly that lodges in moſt parts, and the fat. But if we may be allowed to form a judgment from thoſe profuſe hæmorrhages, that have been ſuſtained without deſtroying the life of the patient, with experiments made on living animals, by drawing out all their blood, joined with the bulk of the arteries and veins themſelves; from theſe principles, the maſs of circulating humours will be at leaſt fifty pounds; whereof near a fifth part will be true red blood, current in the arteries and veins; of which the arteries contain only one fifth, and the veins the other four.

§. 168. Nor does the blood always contain the ſame, or a like proportion of thoſe elements or principles, which we have before deſcribed in it: for an increaſed celerity, whether by laborious and ſtrong exerciſes and a full age, (from 30 to 40) fever or otherwiſe augments the craſſamentum with the redneſs, congealing force and coheſion of particles; and the hardneſs and weight of the concreted ſerum with the alcaline principles are, by the ſame means, increaſed, §. 144. On the other hand, the ſerum and the mucus it contains are increaſed by the contrary cauſes, the more as the animal is younger, leſs active or exerciſed, and fed more on a watry vegetable diet, by all which the craſſamentum of the blood is leſſened, and its watry part increaſed. Old age again leſſens the craſſamentum, and the gelatinous part likewiſe.

§. 169. From theſe principles, (§. 136 to 139.) but with a conjunct conſideration of the ſolid fibres and veſſels,* the different temperaments, and morbid conſtitutions of people are derived. For a *plethoric* or *ſanguine* habit ariſes from an abundance of the red globules; a *phlegmatic* temperature is from a redundancy of the watry parts of the blood; a *choleric* diſpoſition of the humours ſeems to ariſe from a greater acrimony and alcaleſcence of the blood, as appears from thoſe who live on fleſh and on the human ſpecies, being ſo much fiercer and more paſſionate than thoſe who live on plants or on vegetable food. As for the *melancholly*, if there is really ſuch a humour in the blood, it ſeems to conſiſt in a redundancy of the earthy principle, §. 169. [With reſpect to the ſolid parts, a greater firmneſs joined with as more exquiſite ſenſibility or nervous irritability, diſpoſes to a choleric habit; and a leſs irritability with a moderate denſity, to a ſanguine habit; and a leſſer degree both of denſity and irritability are to be referred to a phlegmatic temperament. In the melancholly again, a weakneſs of the ſolids is joined with the higheſt degree of nervous irritation or ſenſibility.] But you muſt be careful not to make theſe temperaments as the ſole and limited ſyſtems or claſſes of conſtitutions; which, in the courſe of nature, are found to be not only four, eight, or even thirty-two; but are really diſtinct in numberleſs degrees.

REMARK.

* 'Tis a wiſe caution of our author not to make any deductions phyſiological or therapeutical, unleſs the conjunct ſtate of the ſolids enters the conſideration. The quantity or quality of the blood vitiated or offending are not the primary cauſes of ſlow diſeaſes, but the effects of a vitiated ſtate of the ſolids, and their actions, by which the blood and all other juices are moulded or compoſed, and to the ſtate of which their quantity and quality are anſwerable; and, for this reaſon, all

good profeſſors have propoſed the conſideration of the elaſtic moving fibres and veſſels, as the neceſſary ground-work or foundation to a knowledge and cure of diſeaſes.

§. 170. The red parts of the blood ſeem chiefly of uſe to generate heat, ſince they always abound in proportion to the natural heat of the animal. Theſe being confined by the largeneſs of the globules, within the red and firſt order of veſſels, hinders the collapſion of their extremities; and in receiving the common motion of the heart, by the greater denſity of their parts, they hold the motion longer, or make a greater impetus aud attrition upon the leſſer orders of humours, upon which their motion is impreſſed. And hence it is, that the red part of the blood, being too much diminiſhed by profuſe bleedings, there follows a ſtagnation or leſſened motion of the humours in the ſmaller veſſels, whence fatneſs, coldneſs, dropſy, &c. By the ſame rule alſo, a due proportion of the ſaid red blood is neceſſary within the habit, to generate and repair new blood for the uſes of the whole ſyſtem. For, by large hæmorrhages, we ſee the blood loſes its red or denſe nature, and degenerates into a pale, ſerous or watry ſtate.

§. 171. The hardening ſerum (§. 157.) is more eſpecially deſigned for the ſecretions and nutritions of the parts, as will be hereafter more apparent (§. 239 to 243.) The thinner juices thence ſecreted have various purpoſes, as the diſſolution of the aliments, the moiſtening of the external ſurface of the body, and ſurfaces of the internal cavities, to preſerve the flexibility of the ſolids, and conduce to the motion of the nerves, the ſight, &c.

§. 172. Therefore health cannot ſubſiſt without a denſe and red blood, whoſe quantity too much diminiſhed cauſes a ſtagnation or ſlow ropy trailing of the juices within the ſmaller veſſels; whence cachexy or paleneſs, coldneſs, weakneſs, and the like. Nor, on the other hand, can life or its proper offices be carried on, or health ſubſiſt without a ſufficiency of thinner juices intermixed with the red blood; which, being deprived of its watry part, congeals and obſtructs the ſmalleſt paſſages of the veſſels, and kindles too great a heat.

§. 173. If it is aſked, whether there be any difference betwixt the arterial and venal blood? we anſwer, that ſome difference there ſeems to be; the former, having lately paſſed the action of the lungs. But, in experiments, I ſcarce find any obſervable difference either in colour, denſity, or any other known diverſity. For the circulation is very quick, and the venal blood itſelf was but a little before arterial. [However, the arterial blood is apparently of a more bright or ſplendid red, and having a greater degree of fluidity and proportion of watry parts, may ſo far differ from the venal darker coloured blood. But, in this reſpect, it remains that we make further experiments.]

§. 174. From one and the ſame maſs of blood, driven into the aorta, are generated all the juices or humours of the human body,

which,

which, from their affinity one to another, are reducible to certain claſſes following; but the manner or artifice, by which each of them are ſeparated, ought to be accounted for by the fabric or mechaniſm of the glands themſelves.

REMARK.

As the blood runs quicker, and into commixture in the veins, as it comes nearer the heart, ſo its particles move more ſlowly towards a ſeparation in the arteries, as they get farther from the heart, with a diminiſhed impulſe. Thus the motion of the blood in the arterial and venal veſſels may be, in general, compared to a body aſcending perpendicularly, contrary to the force of gravity, by ſome impulſe, and with a momentum or celerity continually leſſening; and then returning or deſcending with a celerity perpetually increaſing: only, in the blood, this retardation and accelaration are neither made uniformly, nor in any certain or regular proportion, with reſpect to the diſtances from the heart; becauſe the diverſity of ſtrength, ramification, convolution, &c. of the veſſels themſelves, in which it moves, are irregular and unlimited.

* * *

LECTURE VIII.

Of the ſecretions.

§. 175. THE claſſes or tribes of humours, which, being depoſited or ſtrained off from the blood into other veſſels, are ſaid to be *ſecerned or ſecreted*, ſeem reducible to four; of which the *firſt* includes all the viſcid and lymphatic juices, which, by fire or alcohol vini, turn into a hard coagulum; although generally in the living animal, they are capable of flying off in form of a vapour, and after death are within the ſame veſſels compacted into a gelatinous thickneſs. To this claſs belong the vaporous juices of the ventricles of the brain of the pericardium, pleura, peritoneum, vaginal tunic of the teſticle, of the amnios, joints, and probably of the womb, with the juice of the ſtomach and inteſtines, of the renal capſules, and laſtly, the lymph itſelf, commonly known and called by that name.

§. 176. The *ſecond claſs* is of thoſe juices, which are ſome of them exhalable, like the former (§. 175.), but being more ſimple and aqueous, are neither to be coagulated by fire, nor by rectified ſpirits of wine; and others of which do not exhale, but, being depoſited in their reſpective excretory ducts, are expelled by ſome common outlet, proper to a part of ſome gland. To the former of this claſs belong the perſpirable matter of Sanctorius, and probably the internal perſpirable matter of the epithelium and cellular ſubſtance, with part of the tears and watry humours of the eyes. To the latter of this claſs belong the remaining part of the tears, the ſaliva and pancreatic juice, that of the renal capſules, and the urine. The ſweat ſeems to be a mixture of the perſpirable matter and the ſubcutaneous oil.

§. 177. The *third claſs*, differing from both the preceding, includes the viſcid, ſluggiſh or ropy juices; but ſuch as are of a watry diſpoſition, and not congealable into a jelly, but hardening into a cruſt-like or ſcaly ſubſtance, by exhaling their water. Of this ſort are all the kinds of *mucus* in the human body, ſpread through all the internal paſſages for air, aliments or urine; the cavities of the genital parts, liquor of the proſtates and ſeed, to which add the black humour of the uvea in the eye.

§. 178. The *fourth and laſt* claſs is that of the inflammable juices, which, at their firſt formation, are indeed thin and watry, but, by time, ſtagnating and exhaling their more watry parts, become a thick, oily, inflammable liniment, often very bitter. To this claſs we refer the bile, ear-wax, ſebaceous and oily liniment of the ſkin, the marrow in the bones, and all the fat of whatever conſiſtence, or in whatever part ſeated throughout the human body. And the milk itſelf, ſo far as it is butyraceous and inflammable, belongs to this claſs.

§. 179. Thoſe who conſider, that in the blood are found a coagulating ſerum (§. 156.), an exhaling water (§. 160.), a ſort of viſcid mucus (§. 156.), and laſtly, a thick and thin oil (§. 160.), may thence begin to perceive the poſſibility of a ſeparation to be made from the blood of all the foregoing claſſes (§. 175 to 179.) of humours; in as much as we thus ſee their conſtituent principles are already in the maſs of blood itſelf. But in what manner it is brought about, that oil is ſeparated from the blood in one part, a watry liquor in another, or a gummy mucus in a third, is a taſk that ſtill remains to be explained, and requires a previous deſcription of the ſecretory organs themſelves.

§. 180. The albumenous or hardening juices are ſeparated almoſt every where from the arteries themſelves, into continuous excretory canals, without any intermediate organ or machine betwixt them. The proof of this we have from injections of fiſh-glue, water, and thin oils, which very readily paſs the red arteries, and are poured out like unto ſweat into all the cavities of the body (§. 175.), in which we naturally find the ſaid ſerous vapours in form of a coagulable water; nor do the injections in this courſe meet with any intermediate knots, or ſtops from any hollow cavities and cells. Finally, the blood itſelf, being ſo readily poured out into moſt of theſe cavities, without any permanent damage, when its courſe is either much obſtructed, retarded or urged with a greater impetus through the arteries,

ſhows

ſhows plainly that there is a ſhort and open way betwixt the red blood veſſels and thoſe excretory ducts; [whence the yellow ſerum differs not much from the cruor.]

§. 181. Among theſe juices we reckon the venal lymph, mentioned (§. 51.) before, which paſſes through the valvular pellucid veſſels to the thoracic duct. For this ſeems to be drawn off immediately from the arteries, if we give any credit to the numerous experiments of great anatomiſts, which ſhow that red blood, mercury and other liquors paſs from the ſanguineous arteries directly into the valvular lymphatic veins themſelves. The credit, both of this fact and the experiments, is alſo further confirmed by the mixture of redneſs and yellowneſs, often obſervable in the lymph itſelf; and which, by the microſcope, is a demonſtration of the red ſanguineous and yellow ſerous globules, which paſs and float in the lymph, §. 161. and ſeq.

§. 182. It muſt not indeed be denied, that theſe lymphatic veſſels have a ſort of peculiar glands to themſelves, into which the ſaid lymphatics depoſite their contained juice, and then convey it away from them again. But then the lymphatic veſſels do not ariſe in theſe glands, with which they only communicate in their paſſage. For they ariſe viſibly enough upon the ſurface of the lungs, liver and inteſtines, and run on for a conſiderable length before they enter thoſe glands.

§. 183. Theſe glands then ſeem to contribute ſomething peculiar to the lymph and chyle in their courſe, more than has hitherto been well diſcovered. The ſtructure of them here follows. They appear, as they are called, *conglobate*, or of an oblong, olive-like figure, ſometimes ſolitary, but often in cluſters, and looſely wrapped up in the cellular ſubſtance, in which they enjoy a ſort of free liberty or floating motion, in moſt of the internal parts of the human body, and in many of the external parts. Among the latter we may reckon thoſe which, ariſing in the face and upper part of the parotid gland, and angle of the lower jaw, deſcend along the ſide of the neck with the jugular vein; from thence dividing as it were, or receiving troops from the arm, they paſs on in a direct courſe with the ſubclavian vein to the arm-pit, where they are moſt numerous. Some again are extended as far as the flexure of the elbow or cubitus itſelf; but none appear on the reſt of the upper limb, nor upon all the back.

§. 184. In the thorax they deſcend in great numbers with the wind-pipe, and along the ſides of the pericardium; others deſcend upon the anterior face of the vena cava and pericardium down to the diaphragm. Poſterior lymphatics there are many, encompaſſing the wind-pipe on all ſides, and playing round its ramifications, reach to the extremities of the lungs; while thoſe in the poſterior mediaſtinum ride over the pericardium, and with the thoracic duct extend to the diaphragm.

§. 185. In the abdomen laſtly, there are others called the lumbal lymphatics, which form a conſiderable troop in the folding of the groin, from whence extending along with the great blood-veſſels in the courſe of the Sartorius muſcles, they vaniſh in the ham or bending of the knee. Other lymphatics paſs from this inguinal troop into the pelvis, and continue their courſe upwards through the cellular ſubſtance, behind the rectum, and along with the large hypogaſtric blood-veſſels. There are alſo ſmall lymphatic glands of the ſame kind, with their reſpective troops, ſeated in the greater and leſſer curvature of the ſtomach, at the origin of the great and little omentum, at the entrance of the porta into the liver, in the courſe of the ſplenic blood-veſſels near the ſpleen, and laſtly, through the whole extent of the meſentery and meſocolon.

§. 186. The common fabric of theſe lymphatic glandules is, that they all conſiſt of a ſtrong, external, ſmooth membrane, painted with many red blood-veſſels; within which is a ſoft and lax cellular ſubſtance, but of a ſhort extent, betwixt the cells of which run numberleſs ſmall blood and lymphatic veſſels. As for any folliculus or concavity, muſcular fibres, or duplicate membranes, they are to me unknown.

§. 187. That theſe glandules are of ſome uſe to the lymph and lymphatic veſſels, is certain enough; becauſe we ſee no lacteal or lymphatic veſſel ever reaches to its inſertion, without firſt diſtributing its branches through one of theſe glands, and receiving reductory branches from thence. The chylous juice, with which theſe glandules are filled in children and other young animals, and the ink-like juice which they contain in the breaſts of old people, proves that there is ſomething ſeparated from the blood in theſe glands, and poured into the lymph and chyle, which are here probably expelled into the cellular ſpaces of the gland. Their greater magnitude and more perfect ſtructure in the younger animals, with the ſhrinking and corruption or deſtruction of them in adults and old people, perſuade us, that this their ſecretion is more perfectly made in the younger animals, and that it periſhes in the older. And no part is oftener ſchirrous than theſe; whence it is not probable, that the lymph is in them accelerated. The thymus is of the conglobate kind of theſe glandules, but divided into lobules; but there are found alſo in the groins, arm-pits, and other parts, conglobate glandules of this ſort, collected into cluſters.

§. 188. Another coagulating juice, which hardens likewiſe by mineral acids and alcohol, is the albumenous humour of the joints, which mixed with ſome fat and medullary oil, makes a moſt ſoft or ſmooth liniment, to lubricate the heads of the bones and leſſen the friction of the joints. For the ſeparation of this liniment, certain conglomerate glandules of a peculiar fabric are aſſigned, which are uſually ſo placed in the rough ſinuoſities of the joints, that they ſuffer a moderate compreſſure, increaſing their diſcharge, without bruiſing, by the motion.

§. 189. Theſe mucilaginous glandules have a peculiar fabric. The larger of them reſt upon the bones with a broad baſis, from whence they are gradually extenuated or acuminated into a ridge, from the thinneſt margin in which they depoſite their juice by open ducts. They have a good deal of fat intermixed, and are manifeſtly compoſed of leſſer bunches. Others ſtill ſmaller are ſcattered about the vaginal capſules of the tendons, and betwixt the dividing fibres of the tendons, which laſt ſeem to be almoſt of the nature of ſimple glandules, turgid with a yellow mucous ſerum.

§. 190. The uncoagulable juices of the firſt ſort (§. 176.) are ſecreted in the ſame manner with thoſe which harden (§. 175.), to wit, from the exhaling arteries, which ariſe from the red ſanguineous arteries, without any intermediate follicle or cavity betwixt them. Thus the veſſels, which pour out the perſpirable matter through the ſkin and lacrymal ducts of the firſt ſort, ſuffer a watry or thin gluey injection to tranſude ſo readily from the arteries, as leaves no room to doubt of this truth. [And theſe ſecretory ducts have alſo a conſiderable degree of irritability; whence, by any ſtimulus or contact of acrid particles, they diſcharge more juice in a given time, than what they diſtil in a ſtate of health.]

§. 191. But in the latter ſalival kind of that claſs, the ſecretion is made by means of conglomerate glandules, which the ancients ſo called from their cluſter-like fabric, and eſteemed them almoſt the only proper glands. Theſe are compoſed of roundiſh lobules or cluſters (ſomewhat like thoſe in bunches of grapes, currants, berberies, &c.) looſely conjoined together into larger maſſes by the yielding cellular ſubſtance, which, at laſt, often forms a denſer coat or covering to the whole, like as we ſee in the parotid and maxillary glandules. Through the intervals, betwixt theſe glandular cluſters or grape-like bunches, run the arteries and veins, which are here large or conſiderable enough. But moſt of the conglomerate glandules ſeparate their juices in ſuch a manner from the blood, and from thence, diſcharge it ſo, that each grape-like portion ſends out an excretory duct, which, joining with others of the ſame kind, form larger trunks, which, at laſt, in the manner of a vein, end in one canal, which conveys the humour, ſeparated by the gland, to the part for which it is deſigned, as the cavity of the mouth, inteſtines, ſurface of the eyes, &c. There are, indeed, ſome of theſe glands in which the ſaid excretory ducts are either not preſent, or, at leaſt, not yet diſcovered; as we obſerve in the thyreoidal glandules, thoſe called capſulæ renales, the thymus, and the pituitary glandules.

§. 192. The *acini* or kernels of theſe conglomerate glands are each of them circumſcribed and limited by a harder ſtratum of the cellular ſubſtance; by which ſubſtance they are alſo ſubdivided into leſſer acinuli, as is evident to the eye, and by the microſcope. But it may be queſtioned, how does this ſubdiviſion end? whether or no is every ſimple acinus or kernel hollow in its middle, that, by receiving the humour tranſuding from the arteries into the follicle or cell, it may be ſent out thence by the excretory duct? whether or no are we perſuaded to believe ſuch a fabric obtains from the ſmall ſhot-like ſtones and hydatides bred in theſe glands, with the round ſcirrhi that ſometimes fill the kidneys? whether is this opinion made probable by the morbid round concretions formed in the liver, ſpleen, kidneys, teſticles, and cortex of the brain? or from the bunch-like diviſion or appearance, which thoſe viſcera have in younger animals? [whether the cellular ſubſtance, that ſurrounds the extreme vaſcules in all parts, does not communicate by open areolæ or cells, in which a ſecreted humour is poured by theſe glandules?]

§. 193. In ſhort, none of theſe arguments appear true or concluſive. For the acini, which are found in the viſcera of brute animals, are component lobules, and not elementary parts; but are large and compounded, for the conveniency of each beaſt. The morbid concretions are almoſt all of them a ſort of placentulæ formed in the loculi of the cellular ſubſtance, and take up their ſeat even in the limbs themſelves, where there is not the leaſt room to ſuſpect any thing of a glandular fabric; and are compoſed, as to their matter, of oil, earth and vaporous particles, extravaſated into ſome of the leaſt interſtices of the cellular ſubſtance, where, ſtagnating and compreſſing the adjacent follicles, they form to themſelves proper membranous tunics. On the contrary, the watry and fluid nature of the juice, ſecreted in theſe glands (§. 176.), are arguments that it meets with no arreſtment in the ſeparation, nor places of ſtagnation in its way. For all the juices, which reſt any time in the warm cavities of the human body, which are full of abſorbing veſſels, are each of them more or leſs inſpiſſated, and approach either towards a mucous or an oily diſpoſition. Moreover, if there were any ſuch arreſtments, anatomical injections would meet with more difficulty in paſſing from the arteries into the excretory ducts of thoſe glands; which, under ſuch circumſtances, would be impervious to thick injections, and thin ones they would exhale into their cellular fabric. Yet we ſee that the ſuperlative art of great anatomiſts has not only conveyed injections, but even thick ones like wax, directly from the arteries of the ſalival glands, liver, &c. into their excretory ducts, and this without filling up any intermediate knot-like cavities, which, according to the foregoing hypotheſis (§. 192.), they ought to exhibit.

§. 194. Therefore the *acini* or kernels of theſe glandules appear compoſed merely of arteries and veins (which laſt include excretory ducts) divided and ſubdivided, parted and connected by the intervention of a good deal of cellular ſubſtance, whoſe ſtrata growing gradually more compact or firm as they enlarge, at length ſhow their contents moulded into a ſort of globular nut-like figure. In the belief of this, we are confirmed by analogy in the lobes of the lungs, the lobules of the thymus, and from the ſtructure of inſects, but more eſpecially the fabric of the teſticle, in which we plainly ſee, that lobules are formed of excretory ducts, connected together in faſciculi by a very ſoft cellular membrane. [But they ſeem not to pour their juices into a cellular fabric, which would intercept or make difficult the paſſage to an excretory duct.]

§. 195. Thin watry juices, neither coagulable nor wholly evaporating, are likewiſe in other parts generated without the aſſiſtance of conglomerate or kernelly glandules. For thus the urine is depoſited from the red or ſanguineous arteries into membranous pipes, with which they are manifeſtly continuous, and form an eaſy way, admitting air, water, and mercury to paſs in like manner. And after the ſame manner, though leſs evidently, the nervous juice ſeems to be ſeparated in the brain.

§. 196. The third claſs, or *mucous* juices (§. 177.) are indeed almoſt every where ſeparated into, and diſcharged from ſinuſſes or hollow glands. Theſe true glands or follicles have, in general, ſuch a fabric as makes up an ample cavity, every way circumſcribed by a membrane; but in ſuch a manner, that the fleſh itſelf of the part, to which the gland adheres, is often taken for another cloſe hemiſphere of the follicle. The ſaid cavity or follicle is for the generality round, but ſometimes it is oblong, and obliquely creeping betwixt the adjacent parts; as for example, in the urethra of the male, and in the follicles of the ſinus muliebris.

§. 197. Into theſe follicles or cells the leaſt arteries (or the vaſcular fleſh ſurrounding each crypta or cell, and compleating its convexity) open by producted extremities within the cavity of each crypta, into which they diſtil or exhale their reſpective juice, where, being retained from the narrowneſs of the excretory duct, the more watry parts are drawn up by the abſorbing veins, which correſpond to, and reſemble the exhaling arteries; and thus the follicular or cryptal juices receive a conſiderable degree of thickneſs. The truth of this we are taught from the ſtructure of the ſimple follicles, obſervable in the tongue, in which both the importing arterial ducts or pores, and likewiſe the excretory mouth, are viſible to the eye; and from the velvet-like tubuli lining the ſtomach of birds, quadrupedes and mankind, in each of which an importing ſmall artery, a reductory vein, and an excretory canal, appears to open pendulous in the cavity; and laſtly, from injections, which diſcharge a colourleſs wax into the ſimple glands.

§. 198. Whether the mucous cavity of ſuch a glandule be long or round, it has always an excretory duct, which, for the moſt part, is none of the leaſt; although, in the round mucous glandules, the diſcharging duct or orifice be leſs, in reſpect to the reſerving cavity, than in others. This diſcharging orifice often opens into the common large cavity, into which the mucus is to be poured, without any intermediate duct; for thus it is in the back of the tongue, and in the ſimple glands of the ſtomach and inteſtines, where they have been denominated cryptæ or cells by Ruyſch. The ſinuſſes have often the like fabric, opening without an intervening duct, as in the urethra of the male.

§. 199. Another kind of theſe mucous glandules are thoſe, which we commonly call *conglutinated*; where many ſimple follicles are folded up together in one common covering, and open with their gaping orifices into one common ſinus, without forming any true excretory duct. This fabric we obſerve in the tonſils.

§. 200. Other ſimple glands of this claſs have an *excretory duct*, by which they expel their mucus, namely, a narrow, membranous, cylindric, ſmall veſſel, opening with its poſterior orifice into the cavity of the glandule; and with its anterior orifice into the common cavity, for which its mucus is deſigned. Theſe excretory ducts are of conſiderable length in the ſubcutaneous and ſebaceous glands, and in thoſe of the palate and wind-pipe. In ſome parts alſo, the pore or orifice, and its duct, are more eaſily demonſtrable, than the follicle or body of the gland itſelf; as in the noſtrils, larynx, rectum, &c.

§. 201. In others again, an aſſemblage of theſe ducts, ariſing each from its reſpective follicle, run together into one like the branches of a vein, ſo as to form a conſiderable excretory canal, common to a number of follicles. To this kind belong the compound mucous glands of the inteſtines, ſome of the larger in the cavity of the urethra, with the blind or impervious duct or ſinus at the root of the tongue, to which, in brutes and birds, add the fringe-like tubuli of the ſtomach. The glands of this ſort may be called *ſimple ones compounded or continuous*; but where they lie only contiguous one to another, they may be called *ſimple aggregate* or congregated glandules; as are thoſe of the fauces, ſtomach, inteſtines, &c.

§. 202. The inflammable juices (§. 178.) are ſeparated by organs differing in their fabric. The fat and marrow are depoſited, without the intervention of glands, from the ſmall mouths of the leaſt arteries into the cellular coat or rather ſubſtance; and the ſame fat again eſcapes from under the ſkin by ſmall pores or ducts, without the aſſiſtance of any glandular follicles. But the ear-wax, and the waxen or ſewety liniment of the ſkin, are ſeparated by glands of divers kinds. Moſt of the ſebaceous glandules are viſible enough, with an open or naked mouth in the ſkin, that leads immediately into the follicle, without any duct of conſiderable length; as we ſee in the external ears, noſe, rings about the nipples, in the female nymphæ, and the valley or groove that runs betwixt them and the external labia, in the clitoris and in the male glans and præpuce. Theſe differ but little from the cryptæ (§. 187.) except in their contained matter, which they ſeparate.

§. 203. There are others of the ſebaceous glands, which have an excretory duct of a conſiderable length, like moſt of thoſe in the ſkin, which, being ſeated in the cellular ſubſtance, have conſequently a duct long enough to perforate the ſkin. Thus we ſee it is in the face more evidently, where the length of the duct is often to be meaſured by the concreted maggot-like ſubſtance preſſed out; the bulk of which demonſtrates, that a follicle or cell lies under the narrower pore.

§. 204. There are ſtill other ſebaceous glands of the continous or conglomerate kind (§. 201.) in which many cryptæ by ſmall ducts meet together in one larger excretory duct. Thus in the face, in ſeveral places, there are large pores in common to a number of ſubjacent cryptæ. And of this kind are thoſe ſebaceous ſinks or little inteſtines in the eye-lids: and thus it is in the organ which ſeparates the ſebaceous perfume in the ſebaceous glandules of the muſk-goat of America.

§. 205. The milk, being a humour of its own particular kind, formed of oil and watry juices intermixed, is ſeparated by conglomerated glandules, whoſe fabric we deſcribed at §. 191. Whether the ſecretion of the bile be glandular, is controverted; but there are many arguments to perſuade us, that the liver is a mere vaſcular fabric, whence the bile diſtils immediately from the extremities of the porta into the *pori biliarii* or roots of the biliary ducts, without paſſing any cells or follicles by the way; and in this we are more eſpecially confirmed by the Ruyſchian art of injection, in which the wax paſſes directly from the porta into the biliary ducts, without exhibiting any intermediate knots or ſtoppages; and therefore we ſee the milk and bile are both of them much thinner and more watry than the fat, or the ſebaceous matter, which thicken in follicles.

§. 206. It now remains for us to enquire, how from one common maſs of the blood, the ſame variety of peculiar juices are conſtantly ſeparated, each in their reſpective places; ſo that we never ſee milk ſecreted in the kidneys, bile in the thymus, or mucus in the ſebaceous glandules. This problem, indeed, may be ſolved by one, who ſhall have previouſly acquired a thorough knowledge of the intrinſic fabric, that obtains in each ſecretory organ. In the mean time, we ſhall here propoſe what has been hitherto advanced with certainty on that ſubject from any known principles, whoſe truth we are convinced of.

§. 207. And firſt, the blood itſelf, from whence the humour is to be ſecreted, undergoes a ſort of hygraulic preparation in the various parts, by which it puts on ſuch a character or diſpoſition there peculiar to itſelf, that more particles of a like nature with the humour abound in that blood, which *nature* intends to ſeparate from it. In the liver, the venal blood arrives with a very ſlow motion, full of oil, and full of the ſemiputrid vapours of the inteſtines. At the teſticles, the blood is brought ſlowly through very long ſlender and inflected canals, ariſing at very ſmall angles, and paſſing out of the abdomen through a cold tract under the ſkin. In the carotids, it is probable that the denſer parts of the blood aſcend, while whatever is more watry deſcends into the abdomen and to the kidneys; alſo to the forming of the ſalival juice of the pancreas, liquor of the ſtomach and inteſtines.

§. 208. Another preparation of the blood towards ſecretion, is from its retardation in the leaſt veſſels: whereby the red and denſer parts go on by themſelves along the axis of the canal, while the other lighter and more ſluggiſh, or viſcid and leſs moving particles, recede to the lateral opening or branches, ſo as to enter the ſecretory orifices, which paſs out from the ſides of the ſaid veſſels.

§. 209. The *lights* of theſe lateral or ſecretory orifices, though of different diameters in different parts, are yet always ſmall enough, in their healthy and natural ſtate, to refuſe the red blood. Hence, therefore, we may conclude, that, being enlarged by an increaſed force of the heart, they every where admit a good deal of the red blood from the ſanguineous artery, which they ariſe from, and open into; being in their natural ſtate not much leſs than the red globules. And hence the ſame ſecretory orifices or ducts, which refuſe thick injections of wax or ſewet, do, nevertheleſs, generally admit thinner liquors injected into the arteries. Therefore this is the firſt and moſt ſimple mechaniſm, or machine of ſecretion; viz. that the light or opening of the excretory duct may admit only ſuch particles as have their greateſt diameter leſs than the diameter of the ſaid opening. From this reaſon only, it is, that the yellow arteries convey off a pure liquor from the blood, and that the uriniferous ducts exclude both the red blood and coagulable ſerum. [But this is not the ſole cauſe, ſince the ſame juices are generated by large as by ſmall animals.]

§. 210. Merely by this law, (of the ſecerning orifices) the ſecreted juices may be of many different ſorts: for thoſe, whoſe lights or tranverſe ſections are the leaſt, will receive only the thinneſt juices, as in the ſmall veſſels of the brain; and the larger ducts will admit water and jelly, while the thickeſt fat will enter the biggeſt of all. Moreover, if a number of ſecretory organs are formed in a ſucceſſion from one ſecerning artery, each of them having large mouths or ducts; in that caſe, the laſt, which come out from the ſaid artery, will receive only the thinneſt juices. But if thoſe, which are firſt formed in order from the ſecerning artery, have ſmaller ducts, then the laſt only will receive the groſſeſt juices.

§. 211. From hence it is, that the ſecretions, which are generally made immediately from ſanguineous arteries, without paſſing the ſerous lateral ones, (§. 44.) are all of groſs juices, thick, coagulable or watry; as the fat, urine, juice of the ſtomach and inteſtines, &c. But the other thinner juices are (3.) ſecreted not from ſanguineous, but from ſmaller pellucid arteries ariſing from the former. To the ſecerning mouths, therefore, of theſe laſt not only no red blood, but no ſerum, fat or other groſs juices can have admittance. Thus the more thin and pure humours are ſeparated of conſequence; as for example, in the eyes, cortex of the brain, &c.

§. 212. Some ſhare of the ſecretion ought, perhaps, to be allowed (4.) *to the angle*, which the ſecretory branch intercepts with its trunk. For it is eaſily demonſtrated, that at right and retrograde angles, only the viſcid and ſluggiſh juices are expelled by the ſtronger force of the denſer particles, which hold on their courſe along the middle of the artery; whilſt the denſer go off at half right angles. For thoſe who have made the trueſt obſervations on living animals, have ſeen, that the velocity of the blood is greateſt in veſſels of the acuteſt angles, and leſs in thoſe of right angles. That the effect of theſe angles in the veſſels is conſiderable, with regard to the ſecretion, we are perſuaded from the ſtructure of them in ſeveral parts of the body, ſince they form different angles in different parts, with reſpect to their trunks; and in ſome parts compoſe net-works. For the ſmall veſſels, in general, reſemble the branchings of little trees or ſhrubs, the trunks and arms of them every way ſending out ſmaller branches, but in different angles; at ſmall angles, for inſtance, in the large inteſtines, and at larger angles in the ſmaller inteſtines. Thus in the ſpleen, the ſmall red arteries ariſe ſo thick from their trunks, that they reſemble a wiſk or ſprinkler; in the inteſtines, they reſemble pencil bruſhes, vermicular arches in the kidneys, ſtars in the liver, a radiated circle in the uvea, and in the teſticle, a lock of hair curled up into a button. But we deſervedly receive it as a rule, that the creator never made this diverſity of fabric, without its proper uſe and effects.

§. 213. And (5.) the *inflexions* of the ſmaller veſſels greatly retard the motion of the blood, in which, therefore, the greater part of the force received from the heart, is evidently ſpent in changing the figure of the veſſels. The repeated inflexions, therefore, of the ſecretory arteries increaſe the viſcidity of the juice, by delaying the flux, and giving the parts more time to cohere or attract each other. But a ſtrait courſe of the veſſels increaſes the celerity of their fluid, whence a copious and eaſy ſecretion; but then it makes the ſecretion more un-uniform or impure, as we ſee in the urine.

§. 214. That the ſmaller arteries have (6.) different *degrees of denſity* or firmneſs, there is no reaſon to doubt; ſince we actually find it ſo by experiments in the larger branches. But the denſer the capillary arteries, the more they reſiſt the light and ſlowly moving particles, and yield only to the more denſe ones, that have a greater impetus.

§. 215. And laſtly, (7.) the velocity is greatly increaſed, when the excretory duct ariſes a good deal before the extremity of a larger arterial branch that ends with a ſhort courſe; and is equally diminiſhed, when the ſmall ſecretory artery runs a long way capillary and cylindrical, whereby the blood loſes the greater part of its motion in friction. Finally, from whatever cauſe the diverſity of the blood's motion may ariſe, a greater velocity of it cauſes the ſecreted juices to be more denſe or heavy, more groſs and un-uniform or impure: but ſlowneſs of its motion increaſes the attraction and viſcidity, and probably renders the ſecreted juice more pure and homogeneous, as the ſimilar particles, thus ſorted and brought together, can better attract and join each other under a ſlow motion, ſo as to retain the larger canal, while the thinner parts go off by the leſſer lateral branches. From hence it is, that only the impulſe of the heart being too much increaſed, all the ſecretions are confuſed.

§. 216. From all that has been hitherto advanced, we may now begin to perceive, that, ſince the blood contains particles of various kinds, ſome ſluggiſh or ropy, others mucous, others coagulable; ſome, again, very fluid, others more denſe and red, ſome glutinous, ſome watry and thin, others fat and groſs (§. 175 and ſeq.): among all theſe particles, thoſe, which are the largeſt and moſt denſe, as the red and yellow globules, will go on moſt towards the axis of the veſſel, ſo as to paſs on in a continued courſe from the artery into the trunk of the ſanguineous vein, §. 37.

§. 217. Thoſe particles, which are ramous, groſs and ſluggiſh, as the fat, muſt needs go off laterally by larger orifices from the ſanguineous artery, by ſhort ducts; for long ducts would make a ſtop to ſo ſluggiſh a juice, as the fat or oil. Therefore we ſee, that the circumſtances or phœnomena of the adipoſe ſecretion (§. 20.) agree with this deſcription. Such parts as are coagulable, but ſpecifically heavier than thoſe which are merely watry, kept fluid only while the powers of life are in action; theſe paſs off laterally from the ſanguineous, into the pellucid arteries, leſs than the red arteries, with which they are continuous; whether theſe pellucid ones are continued on in the nature of trunks, ſending off other ſmaller branches, like the leaſt arteries (§. 40.); or whether they exhale their contents by a ſhort extremity, like the veſſels of §. 170.

§. 218. Thin watry juices may evidently paſs off by any veſſels continous with the ſangineous ones or the leſſer ones (§. 44.), provided they be only ſmall enough to refuſe the groſſer juices: and this whether they come out from the ſides of the larger arteries, or whether by a long continued courſe, and ſending off all the groſſer juices by large lateral branches, they, at length, end in a ſmaller pellucid canal inſtead of a trunk, like that which ſupplies the clear contents of the eye. To the production of theſe juices, the moſt ſimple fabric is ſufficient: even a direct continuation of the ſecretory artery itſelf into an excretory duct, as we ſee in the urine. Therefore the ducts and veſſels have here a ſtraight and ſimple courſe, with few or no inflexions, and a proportionable velocity or celerity, as yet holds in the courſe of their contained juices.

§. 219. Such juices, as being watry, light, mucous and viſcid at the ſame time, are conſequently ſluggiſh and leſs moveable; theſe may be eaſily ſecreted by ſhort narrow ducts of a leſs diameter than to admit the fat, and appended to the ſanguineous arteries; and, therefore, it is evident, theſe will be ſeparated from the blood more abundantly in ſome parts of the body than others, namely, where the velocity, received from the heart's impulſe, is leſs, the flexures of the artery more frequent, and where the extent of the capillary artery ſhall be carried to a greater length.

§. 220. Whether or no ought we to aſcribe to each particular part the ferments, pores, ſpecific weights, or filters, which determine the nature of the humours to be generated? one, who admits of theſe, ought to conſider the great difference there is in one and the ſame juice, ſeparated in the ſame part of the body, according to the difference of age, courſe of life, &c. The bile in a fœtus is generated ſweet, the ſemen thin and without vermicles, the milk either none or very watry, the urine watry, mucous and inſipid, the uterine mucus very white, the cutaneous veſſels full of red juices, the lymphatic or watry juices rediſh, and the fat gelatinous. By the ſame organs, in an adult perſon, the bile ſeparated is ſharp or acrid, the ſemen thick, the milk ſweet or oily, the urine yellow, thin and alcaleſcent, the womb diſcharges a menſtrual blood, and lymphatic aqueous humours are moſt clear. But, even in the adult perſon, how different is the urine; at one time watry, at another thick or concocted, in a fever high coloured and heavier, full of ſalts and oils. The paſſions of the mind, which make no other change in the body than that of ſtrictures in the nerves, yet wonderfully change the face of the ſecretions, and expel even the blood and bile through the veſſels of the ſkin. Add to this the frequent diſturbance of the ſecretions, and changes to which they are liable from ſlight cauſes; ſo that only an increaſed celerity ſhall cauſe ſeveral differing liquors to be ſecreted by one and the ſame organ: for ſerum and blood have been known to paſs into almoſt all the paſſages of the ſecreted juices, into thoſe of the ſweat, tears, mucus of the noſtrils and of the womb, and into the lactiferous, ſeminal and urinary ducts, as well as the fat. A true milk has been ſeen ſeparated by glands in the thigh. When the urine has not been excreted by its natural courſe through ſome defect of the kidneys, ureters or bladder, it has paſſed by the ſkin, exhaled into the ventricles of the brain, or even into the whole cellular fabric. The perſpirable matter of Sanctorius, however thin, is often by cold drove through the noſe or kidneys, or by the ſame cauſe, by fear, or by medicines, is depoſited through the excretory villi of the inteſtines. That exhaling viſcid juice, ſecreted by the ſame organ with the fat, from which it ſo much differs, into the cellular ſubſtance, is depoſited, takes place of the fat, is re-abſorbed and alternates again with the ſame, §. 20, &c. A ſalivation ſupplies the place of the Sanctorian or cutaneous exhalation externally, and of the cuticular exhalation internally. The bile re-abſorbed appears evidently flowing in the veſſels of the eyes. Nor does there appear any thing in the fabric of any of the viſcera or glandules that can fix or maintain the nature of the ſecerned fluid; but that a greater or leſs velocity, or a ſtricture of the nerves, ſhall produce differently changed juices in the entire organs.

§. 221. It now remains for us to diſcover, how the ſecretions, in a healthy perſon, become pure or uniform. For all the juices, that have been lately ſecreted, (without excepting any, even the oil or fat itſelf) have a great many watry particles intermixed; ſo that none of the thicker juices ſeem capable of being formed without having a mixture of the thinner watry ones; how then do the ſemen, bile, fat, mucus, and other thick juices depoſite their firſt watry ſtate, and acquire their proper viſcid condition and other qualities?

§. 222. For this end, therefore, nature has framed glands, with large and ſmall follicles or reſervoirs, for retaining the ſecerned juices, from which the watry parts are required to be ſeparated, to render the remaining part more ſtrong and viſcid. The mucus, at its firſt depoſition, is thin and watry as yet, but little differing from the perſpirable vapours or tears, in which ſtate it diſtils into the cavity of the noſtrils, wind-pipe, and inteſtines. This is not continually diſcharging, becauſe the excretory orifice is leſs than the retaining cell or follicle, §. 189. and the excretory duct, being ſometimes long and ſlender, ſo retards the juice that it cannot paſs out but by the aſſiſtance of a preſſure, or often, perhaps, not without a ſort of nervous ſphincter at its orifice, be from the irritating quantity or acrimony of the juice relaxed. This appears from the morning diſcharges of mucus by blowing the noſe, coughing up from the lungs, and by ſneezing after the nocturnal ſtagnation. In the mean time, the patulent veins, extended into the cavity of the follicle, abſorb the more aqueous parts from the thin mucus, that it may become thicker, as it is retained longer; but if, by the force of ſome ſtimulus, it be directly diſcharged after it is ſecreted, it comes out thin and watry. Examples of this we have in the urethra, in the noſtrils and in the ear-wax; as alſo in the bile, which, at its firſt ſeparation in the liver, is watry, and has but little yellowneſs or bitterneſs. It is, therefore, retained by a large follicle or gall-bladder, and there digeſted or exalted by the vital heat, and its more thin or watry parts exhaled or abſorbed by the veins; whence the remainder becomes more thick, bitter and oily, or ſaponaceous. The ſame mechaniſm takes place in the ſemen, which, being reſerved in the ſeminal veſicle, is there thickened, ſo as to be very viſcid after long chaſtity; but in repeated venery 'tis expelled very fluid. In ſome places nature has made this receptacle two or three times folded together in one and the ſame organ, when her deſign was to form a very thick juice. Thus the ſeminal paſſage is in the teſticles reticular, in the end of the epididimis one large canal, ending in a larger veſicle; whence the veſſels at the teſticle are narrow, and ſo again are the vas deferens with the proſtatic duct.

§. 223. Hence, therefore, there are never any glandules placed in a part, but for the ſeparation of a viſcid juice; or if a viſcid liquor is any where ſeparated from the arteries without a glandular or follicular fabric intervening, it then always ſtagnates in ſome larger veſicle or cavity, of which we have examples in the ſeed, bile, ſynovia of the joints, and in the fat.

§. 224. A ſecerned juice may be likewiſe changed in its receptacle by irroration or the affuſion of ſome new liquor. Thus the ſemen thickens by an affuſion of the proſtatic liquor, the chyle is thinned by mixture with the ſaliva and pancreatic juice, and that which diſtils from the villi of the ſtomach and inteſtines, and by an affuſion of the bile it becomes alcaleſcent; and again the ſynovia or albumen of the joints is tempered by fat and medullary oil, §. 188.

§. 225. But the great uſe of the follicles and receptacles of glands is to preſerve the juice, of whatever kind it be, for thoſe times in which it is moſt neceſſary to be employed in the actions of life. Thus the bile is reſerved for the time of digeſtion, the ſemen for due and lawful venery, and the mucus of the noſe is accumulated in the night to temperate the force of the refluent air in the day.

§. 226. Therefore as nature has in this way framed machines, by which the juices are retarded in the large and ſmall follicles, ſo ſhe has made others to expel them at ſuch convenient times. To ſome glands ſhe has given particular muſcles for this uſe, as in the teſticles of brutes, the urinary bladder and the gall-bladder; or elſe ſhe has placed other muſcular machines round them, which, by acting at convenient times, expel the contained fluids; as for example, in the muſcular coat of the ſtomach and inteſtines. In other parts ſhe has added contiguous and incumbent muſcles to promote the diſcharge, as in the biventers and maſſeters of the lower jaw; or elſe ſhe has again joined to them a kind of nervous irritability, which, being excited to action by an unavoidable ſtimulus, opens the ſhut paſſages to the milk, ſeed, tears, &c.

§. 227. The ſeveral particular juices, which are derived from the blood, we ſhall deſcribe more accurately, under their reſpective organs. But before we deſcend to the particular ſecretions, it was neceſſary for us firſt to ſpeak of ſecretion in general, and eſpecially of that univerſal one, which is made of the nutritious ſerum or lymph through all parts of the body; thus we may next proceed to the appoſition or accretion of it, to ſupply the deficiency of ſuch parts as are daily waſting in the human body.

LECTURE VIII.

Of nutrition.

§. 228. THE human body is made up of ſolids and fluids (§. 1.), of which the latter appear to be in much the greater proportion, if we conſider their origin from a fluid nouriſhment, the great quantity of the blood (§. 167.), the proportion of the lights of the veſſels to their fluid contents, the filling of the veſſels by waxen injections, the ſmall weight or bulk to which the body is often reduced by diſeaſes, by putrefaction or a chemical diſtillation, or by an exhalation of what is more fluid.

§. 229. That the fluids are perpetually waſting is eaſily demonſtated. Thoſe which are watry, are the moſt readily thrown out of the body. The Sanctorian perſpiration, with that of the lungs, often amounts to three and four pounds per diem. But even the thicker coagulable juices are perpetually diſſolved by the healthy human heat, equal to 96 degrees, joined with the attrition of the globules among themſelves, and againſt the ſides of the arteries (§. 148.); 'till being ſufficiently volatilized, they, at length, fly off or eſcape. Even the urine is neither wholly a watry liquor, nor compoſed merely of the recrementitious parts of our aliments, but is in part formed of our worn-out humours, ſince it is found alcaleſcent and replete with the ſame kind of oil, earth, fixed air, and ſpirit, which the blood itſelf contains. Part of the bile alſo and of the inteſtinal juices are daily excluded by ſtool, to the quantity of ſome ounces. A further proof of this waſte in the fluids, we have from the leanneſs and collapſion of the body that follows great exerciſe, fevers, the force of purgatives, &c.

§. 230. But the fluids are not the only parts of the body which waſte, for the ſolids likewiſe are daily conſumed by their perpetual actions in life. This is eaſily proved from the waſting cauſes themſelves; for the blood, being thrown with great impulſe by the heart into the convexities of the crooked veſſels, extends them in all their dimenſions, both as to length and breadth; ſoon after which, the ſtraightened veſſels return by their elaſticity again into their wrinkled or vermicular poſitions; and this change they ſuffer an hundred thouſand times in a day, by a force ſufficient to grind even wood or metals: ſuch a friction muſt, therefore, of courſe conſume the looſely cohering parts of our body, made up of a friable earth and glue (lect. I.), eaſily reſolvable by fire or putrefaction. This friction happens in all the veſſels, but is more eſpecially enormous in the leaſt veſſels; while the fibres are extended in length, the intermediate glue likewiſe, by the extenſion, loſes of its attractive force, and if the diſtending or impelling force does but a little exceed that of attraction, the glue muſt be expelled from the intervals betwixt the earthy elements. This is confirmed by ruptures of the membranes of the aorta in old people.

§. 231. That there is a diſſolution of parts in the extreme cut off, exhaling veſſels, both external and internal, made by the force of the blood and juices, is demonſtrable from the looſe and free opening of the laſt elements of the fibres, only one of which adheres to the remaining part of each canal. From hence comes the ſcurf or ſordes made by a conſumption of the cuticle, the quick growth of the hair and nails, with the increaſe of the teeth, which is none of the ſloweſt.

§. 232. That the cellular fabric of the veſſels is wore away not only within their cavities, but likewiſe on all ſides without, will eaſily appear from conſidering the very weak coheſion of this ſubſtance, ſo eaſily diſſolvable by maceration only, with the violent attrition it ſuffers betwixt the impelled blood and the adjacent muſcles, tendons, and contiguous bones. The circumjacent fat, indeed, abates this attrition, but does not wholly remove it.

§. 233. The cellular tiſſue or web-like ſubſtance, which makes the ſolid ſtratum or baſis of the membranes and viſcera, muſt neceſſarily diſſolve and return into the ſtate of a fluid, through an abraſion of fragments, made by the vibrations of the arteries, which are always annexed to it in every part of the body. The ſame diſſolving effects likewiſe have the violent and almoſt inceſſant motions of the muſcles, which, by the repeated flexions and extenſions of their fibres, muſt operate thus in a very conſiderable degree: for the nature of things, in general, demonſtrate this, ſince nothing more powerfully ſoftens or diſſolves the hardeſt bodies than a repeated and ſtrong flexures of their parts; whence of courſe the ſame power will have the ſame effect in diſſolving our cellular ſubſtance, compoſed but of ſoft fibres, lately made out of a gelatinous glue; and ſo far from ſolidity, that it contains many intermediate vacuities, with a diſtinct ſeparation of its thin parts by intervening fluids, §. 10.

§. 234. Even the firmneſs of the bones themſelves does not ſecure them from a ſlow diſſolution, and a perpetual renovation; for that new ſtamina are formed in the hardeſt bones is evident from the morbid protuberances of the teeth in ſcorbutic patients; from the inflexions or curvatures of the fibres of the teeth round ſmall leaden ſhot; and laſtly, from the wonderful overgrowing or ſprouting of thoſe teeth obſerved both in brutes and men, which have long loſt their oppoſites. Laſtly, that the oſſific juice or matter changes, and that the old carried off is ſucceeded or replaced by new matter, appears plainly from the degeneration of ſound hard bones into the ſoftneſs and conſiſtence of fleſh; from the venereal tophi or excreſcences formed by a corrupt oſſific juice, with the incurvation of the bones, that ſupervenes an acrimonious or vitiated ſtate of the juices; and from the removal or cure of theſe by internal medicines: add to theſe, the red colour that is introduced into the ſubſtance of the bones by giving madder with the food of animals, and the diſſipation thereof, or reſtitution of the bones to their natural colour again by changing their diet. Laſtly, that the bones of old people truly waſte or decay, is confirmed by the experiences of many able anatomiſts.

§. 235. Hence, therefore, 'tis evident the whole living body is in a perpetual ſtate of fluxion, conſumption and renovation. The juices we ſee are fuſed, exhaled and expelled. The ſolids are broke and diſſolved into the leaſt ſcales and ſtamina, which, being taken up by the mouths of the inhaling veſſels, and tranſmitted through the larger into the maſs of blood, afford that earthy matter obſervable in the urine and in the ſubſtance of calculi, and præternatural oſſifications formed in divers parts. This conſumption is largeſt in youth, where all the parts are ſofter, and the impulſe greater, the watry and gelatinous principles more abundant than the earthy. This waſte grows leſs with age, but 'tis always conſiderable.

§. 236. There was, therefore, a neceſſity in nature to provide for this conſumption of parts. In what manner the fluid parts are repaired will be eaſily demonſtrable, if you conſider from what we ſhall ſay on the digeſtive powers, that they ſend a chyle like milk from the aliments into the blood, replete with a thin butyraceous oil, and a liquid vegetable or animal jelly. So the globular juices ariſe out of the oily or fat particles, naturally of a globular figure and of a looſer lighter texture than water, by the condenſing powers, viz. the contraction or preſſure of the arteries, and the intrinſic attractive force that prevails in the leaſt veſſels, where the globules are divided by very little water; and laſtly, by the figurative power in the lights or ſections of the leaſt veſſels, whereby they become denſe globules of a certain diameter.

REMARK.

Fat or oil, both animal and vegetable, by triture with water, turns into jelly, and that again, by ſpontaneous reſt and ſeceſſion of parts, turns into oil; ſo that reſins, by triture with alcaline ſalts and water, return to gums, and gums, by digeſtion, in plants with age, turn into reſins. In like manner are animal fat or oil and jelly commutable one into the other. Though we canot think the fat, under its intrinſic oily character, can make an organic part, either ſolid or fluid, even the moſt ſimple, as fibres and elaſtic globules, until it has acquired the elaſtic ropy property of lymphatic glue, by repeated mixture, triture, &c. So fat or oil muſt aſſume the nature of elaſtic glue before it can form organic globules, however looſe, light or minute. Such light looſe globules are abundantly ſupplied, and are ready formed with a nutritious jelly in moſt vegetable ſubſtances, eſpecially fermented, as all pulſe, bread, beer, wine, ſoops, &c. which globular matter, we know by the microſcope, not only abounds in the nouriſhment itſelf, but in the chyle formed thence; ſo the globular juices of fiſh, fleſh, milk, wine, beer, &c. leſs than red blood globules, may enter with the chyle, by the inhaling or abſorbing veſſels in the inteſtines, and by the aboveſaid forces be compacted into red, ſerous, and other globules. So likewiſe, as our author juſtly obſerves, fat or oil, being qualified or granulated, as it were, by the action of bile and other ſaponaceous juices, may, like the reſin of plants, be reduced and ground into gelatinous elaſtic globules, ſtill retaining ſo much of their oily nature as to be inflammable. Thus the fat, in conſumptive people, turns again into blood and nouriſhment; and the redundant blood or nouriſhment from a ceaſing of the menſes at 50, or after other great excretions ſtopped, turn into fat, or elſe give birth to diſtempers.

§. 237. That red globules may be formed out of fat appears from their inflammable nature, §. 165. and that they may be formed of the condenſed globules in the chyle is evident from the uſe of milk, as the beſt and moſt immediate matter for making blood in the fœtus and children, confirmed by the experiments of Lewenhoeck, who obſerved the globules of chyle to be larger and looſer or lighter than thoſe of blood: and experience demonſtrates the ſame, by which we know the chyle ſwims and circulates in the blood very diſtinct, both as to form and colour, for ſome (10 or 12) hours after a meal; but after a longer time, it diſappears, and is found of a nature uniform to the blood itſelf; whence there is evidently a neceſſity for the chyle to change into the other animal humours.

§. 238. To form a coagulable lymph from blood then can be no great difficulty. For this we already have, long before, perfect in the fleſh of animals, as in mutton; ſo that for this there is no other action required from our bodies,

dies, but to extract the ready formed lymph from the ſolid fibres and veſſels, and tranſmit it thence to mix with our blood. And hence it is, that animal food affords the ſtrongeſt and moſt durable nouriſhment, and the moſt immediate recruit to the ſeveral actions or forces. In vegetables, indeed, there is inherent a leſs quantity of the like, viſcid, gelatinous nouriſhment; and therefore they nouriſh leſs. Yet, that vegetables already abound with ſuch a glutinous jelly, as may merely, by the animal powers, be changed into coagulable lymph, is evident in herbivorous game and cattle, moſt of which, feeding only on plants, make thence the beſt glutinous lymph: and laſtly, from the viſcid nature of farinaceous vegetables themſelves, being mixed with water, and from the nature of moſt juices obtained from plants.

§. 239. But that the other humours of the human body are generated of lymph, we are perſuaded from the example of the young of incubated eggs, which are altogether compleatly formed, both ſolid and fluid parts, out of the albumen compacted; which is again confirmed and illuſtrated by the change of the lymph into an evaporable water, by a heat of 96 or 100 degrees, which watry lymph is then ſubalcaline; ſuch as is the perſpirable matter of all kinds.

§. 240. Nor is it very difficult to explain in what manner the waſting ſolid parts are repaired. For the lymph is viſcid, and readily adheres or concretes into a ſolid, as we ſee, for inſtance, in the formation of polypuſſes; and, by repeated concuſſions, (as with a whiſk, &c.) the ſerous gluten,. by removing the watry part, is readily drove together into a maſs, §. 157. Therefore the foveolæ or little vacuities in the veſſels or fibres, made by an abraſion or demolition of the earthy glutinous elements, are filled up by the lymph itſelf, compacted by the impulſe of the blood, into which vacuities, being once received, it coheres partly by a broad ſurface to the other ſolids, and is in part figured, compacted and agglutinated by the impulſe of the arterial juices driving againſt the circumference. [A great portion of this additional matter ſeems to be air abſorbed and conveyed hither by the circulating fluids, and fixed into a ſolid with a greater proportion of earth, glue and water; ſince no diſſolution enſues, unleſs the incorporated air be extricated, and ſet at liberty in elaſtic ſpherules.]

§. 241. As for the decreaſe or waſte that is ſuffered in the extremities of the free pervious veſſels and fibres, that ſeems to be reſtored by mere protuſion, while the place of the decreaſed extremity is filled up by a production or elongation of the next continuous fibre. Thus intervals or vacuities are produced betwixt the protracted fibres, which are filled by new lymphatic glue.

§. 242. The waſted matter of the cellular ſubſtance is reſtored by the lymphatic dew itſelf, which tranſudes through it (§. 20.); for this being poured out wherever there is any waſte or vacuities made in the fibres and plates of the ſaid ſubſtance, being coagulable, it is, by the ſeceſſion of its watry parts, joined with the preſſure of the adjacent muſcles and impulſions of the arteries, compacted together and changed into cellular ſubſtance. This is made clear from the change of vegetable juices firſt into a pulp, and then into a true cellular fabric; and from the morbid connecting filaments, which ariſe in the thorax or pleura from the lymphatic tranſuding vapours, &c. [A ſuppuration, and the converſion of vegetable juices firſt into a pulp, and then into a cellular ſubſtance prove the ſame.]

§. 243. In what manner the muſcular and tendinous fibres are nouriſhed, may be then more rightly explained, when we ſhall have a more perfect knowledge of their fabric. Yet it appears from a compariſon of the ſoft pulpy muſcles in a fœtus, almoſt in every point fleſhy, with the tendinous and but little fleſhy muſcles of an adult perſon, and from the great abundance of the minute veſſels playing round all the muſcular fibres; I ſay, from thence a muſcular fibre ſeems to be nouriſhed by a lymphatic dew, poured out into the cellular fabric that ſurrounds the fibre, with which it joins into coheſion by the muſcular and arterial preſſure.

§. 244. As the fabric of the bones is better known to us, ſo the rationale of their nutrition is more eaſy than the ſoft parts. They are compoſed at firſt of membranous fibres, which by degrees harden, while an oſſifying glue is thrown into the ſpaces betwixt the fibres. This oſſific juice is demonſtrated from its filling the fiſſures that run betwixt the bony plates in a fœtus, which in the adult become exorbitant knots of bone; from the inorganic ſtony cruſt, that is often formed round the bones; and from the frequent anchyloſes, that are formed by the tranſuding of a confuſed bony matter coagulated betwixt any two bones: we have inſtances even where the whole hollow tubes of the larger bones have been filled by a redundancy of this oſſific juice. But that the ſaid juice is a true animal glue, of the ſame nature with the coagulable lymyh, appears from the jellies that are drawn out by fire from bones, horns, ivory, &c. ſo thic or viſcid that they will make more than five times their bulk of water conſiſtent, while the remains of the bone, from whence the jelly was drawn, are left very brittle or friable: but the ſame glue or jelly of the bones is alſo reſolved by putrefaction, and then, like the lymph, it becomes wholly volatile, as we know from undoubted experiments. Laſtly, that a fluid viſcid juice may change into a dry friable nature, is evident from parallel examples in egg-ſhells, ſnails, and other teſtaceous animals; and finally, from the recent bones themſelves tranſuding, bloody and viſcid drops, ſoon changing into a hard bony nature, and from the ſolidity of a burnt bone reſtored by dipping in jelly.

REMARK.

Add to this, that among the nutritious elements of the bones, and other ſolid parts, the fixed, permanent or unelaſtic air (§. 2.) bears a very conſiderable proportion; for thus it abounds not only in the blood, but in the oſſific and earthy juices it is even a ſort of connecting magnet or glue, ſerving to combine and unite the earthy particles one with another, as appears from experiments on animal calculi, foſſil ſtones, and other hard bodies: all which have the coheſion of their parts broke, and become friable ſo ſoon as the ſaid air is expelled from them; although the manner, in which this is effected, be difficult to deſcribe.

§. 245. Thus it appears in what manner the body is preſerved in the ſtate wherein we find it in a healthy perſon, and how thoſe loſſes are repaired, which are perpetually made by the actions of life itſelf. But the ſtandard of nutrition varies in perſons of different ages; for during infancy more is added to the body than is thrown off from it; but in old age the conſumption or waſte is greater than the addition. The former of theſe is called the *growth* or increaſe of the body; and the latter its ſhrinking, *withering* or decreaſe.

§. 246. The fœtus in its firſt rudiments was no more than a little limpid drop of a fluid conſiſtence, as we ſhall hereafter make appear; and even after it has had a month's growth, what are to be future bones appear as yet no more than gelatinous membranes. From ſuch a ſmallneſs then as eſcapes the keeneſt eye is the fœtus increaſed with ſo much rapidity by receiving a milky juice or nouriſhment, that within nine months it exceeds many millions of times its firſt bulk, weighing above a dozen pounds. From the time, therefore, of his birth, being expoſed to the atmoſphere, man increaſes in a leſs proportion, or grows every day more ſlowly, 'till, in the ſpace of twenty years, he ſhall have acquired near twelve times his native weight, with a threefold or fourfold increaſe of length or ſtature. It remains, that we explain the cauſes of this increaſe and the quickneſs of it, during the firſt months; and why this quickneſs of the growth perpetually leſſens.

§. 247. The wonderful extenſibility of the fœtus eaſily appears from the viſcid mucous nature of its whole little body; for while the earthy principles are but few in a fœtus, the watry and ſucculent are more abundant: the veſſels themſelves are alſo infinitely more numerous or abundant, as is evident to the eye, and from injections of the bones and membranes, in which an infinite number of veſſels, not to be found in the adult, are viſible enough; many parts are alſo ſeen vaſcular throughout in a fœtus, inſtead of which, in adults, we find a condenſed cellular ſubſtance, or an extravaſated inorganic juice, as in the cartilages, coats of the veſſels, ſkin, tendons, bones, &c. But the more numerous the veſſels, the more eaſy is the growth or increaſe; ſince into them the juices are carried by the nearer heart, with a greater and more confined impetus. But in the more grown animal, the juices, transfuſed into the cellular ſubſtance, are almoſt ſtagnant, and the extending powers are leſs.

§. 248. But there is ſtill another cauſe neceſſary to be taken into the account, namely, a greater proportion of force or impetus in the younger heart, with reſpect to the primigenial ſolid veſſels and fluid juices in the human body. This is proved by the little heart or point, which immediately appears vivid and ſalient, when as yet none of the other viſcera, nor even any of the future ſolid parts, make their appearance; and hence, of courſe, follows that greater frequency of the pulſe, obſervable in younger animals. For how could the animal grow, if there was the ſame proportion of ſtrength betwixt the tender veſſels and heart of the fœtus, as there is in the more reſiſting adult veſſels and the heart of a grown perſon? And in this, if I am not miſtaken, the greater irritability of the younger heart has a conſiderable ſhare, by which the venal blood operates with a greater force on the heart of a fœtus, than on that of an adult (§. 113.) For we ſee all the ſenſible organs in adults grow callous or leſs moveable, while in the fœtus they are exquiſitely tender and ſenſible; as for example, in the eyes, ears, ſkin and brain itſelf. And is not the ſame greater irritability alſo explainable from the greater magnitude of the head or encephalon; whence the nerves bear a greater proportion to all the other parts in younger animals?

§. 249. The heart, therefore, ſtrongly exerting its force againſt the mucous veſſels, eaſily extends them, together wirh the cellular ſubſtance that ſurrounds them, and likewiſe all the muſcular fibres, at the ſame time, ſpread with variety of veſſels. But all theſe eaſily yield to the prevailing force of the heart, becauſe as yet they contain only a little of the rigid earth, but a great deal of the connecting yielding glue. [From hence come the more frequent hæmorrhages of young folks, who have a greater force of the heart and veſſels not yet rigid.] But the bones are generated in ſuch a manner, that, at firſt, a thick glutinous juice, being poured betwixt two parallel veſſels, and there compacted together, forms a membranous fibre, which, by repeated pulſation of the veſſels, becomes bony. But the bones increaſe, when theſe fibres are once formed, while the continuous lateral veſſels, being extended lengthways by the heart, draw with them and elongate the ſaid cohering bony fibres; by this means the cartilage, which every way terminates the bones, together with the cellular fabric (here compact and elaſtic) are repelled by the ſaid fibres, which increaſe longitudinally betwixt each elaſtic epiphyſis, ſo as to ſhorten and condenſe the ſaid epiphyſes. Thus the length of the parts of the body is increaſed; but, at the ſame time, intervals are left betwixt the elongated fibres of the bones, which, by this means, become cellular, as they grow more earthy. Theſe intervals (by §. 20. and 244.) are filled with juices, which, in younger animals, are more viſcid and glutinous than in adults; by this means the bony fibres and plates adhere one to another, from the glutinous matter fixing, like pegs, into their reſpective intervals or foveolæ.

§ 250. That the younger bones are of a more viſcid gluey nature than thoſe of adults and old people, is evident from the greater degree of flexibility that remains in them, from their eaſier conſolidating when broke, from the greater quantity of glutinous ſerum, and more abundance of jelly obtained from the joints or extremities of younger animals, and the great proportion of the cartilages to the bones themſelves.

§. 251. But the animal grows or increaſes ſlower, as it becomes more adult. This is proved from the rigidity of the parts themſelves, which were flexile in the fœtus; and from many parts of the adult ſkeleton being now rigid bone, which were before mere cartilage. For as the animal grows up, a multitude of veſſels are effaced or cloſed up into fibres, beat together by the internal pulſation of the larger artery that lies betwixt them, or upon whoſe coats they are ſpread; and the lights of theſe being occupied by ſolid matter, they become in a great proportion ſtronger; namely, by the bony juice poured into the clefts betwixt the bony fibres, or by condenſing of the cellular ſubſtance in all the membranes in the coats of the veſſels, &c. But every where in all parts of the body a great portion of the more watry part of the juices being exhaled, the cellular filaments approaching nearer, attract each other more powerfully, cohere more ſtrongly, and reſiſt extenſion with a greater force. At the ſame time the glue itſelf, which every where adheres to the bones and ſolid parts, becomes drier from an expulſion of the watry principle, by the ſo often repeated preſſures of the arteries and muſcles. Hence the proportion of earth in the animal every day increaſes.

§. 252. Thus will all parts continue to augment in bulk and denſity, 'till they arrive at a terminus or balance, beyond which the heart will be no longer able to make an extenſion of the ſolids. This terminus then is preſent or compleat when the cartilages belonging to the epiphyſes or heads of the bones, are, by degrees, ſo extenuated, that they can become no thinner, but like a pellicle, no leſs firm than thin, make a permanent reſiſtance both to the heart and to themſelves. At the ſame time, and from the ſame cauſes, all the cellular fabric or expanſions (except in a few places) are throughout the whole body compacted or hardened, and all the membranes of the arteries, the muſcular fibres and the nerves themſelves acquire from the ſaid cauſes (§. 251.) ſuch a degree of firmneſs, that they can be no longer extended by the force of the heart.

§. 253. The cellular web-like ſubſtance, however, whoſe plates are naturally looſe, lodged in ſeveral cavities of the body, ſtill gives way to the impulſe of the fat and ſometimes to that of the blood, whereby it ſwells or enlarges in ſeveral parts, ſo as to cauſe an increaſe of the body, not in length or ſtature, but in bulk or thickneſs. But this fatneſs of the body, after its full growth, ſeems to follow hence, that leſs nutritious matter being depoſited from the blood, becauſe the growth now ceaſes, there is a redundancy of it towards the other ſecretions; and becauſe the reſiſtance to the paſſage of the humours through the leaſt veſſels is now increaſed from their greater denſity or induration; therefore the ſluggiſh juices (ſuch as make fat) more eaſily recede laterally from the leaſt arteries into the cellular diverticula. But again the ſluggiſh ſecretions muſt, at this time be increaſed, becauſe the relative or comparative force of the heart, as 'tis properly called, is now diminiſhed. For the rigidity of the parts increaſes the reſiſtances, while the force of the heart itſelf does not appear to have gained by the ſaid rigidity; becauſe we know it is a muſcle to the ſtrength of which conduce flexility, a plenty of nervous juice in proportion to its ſolid fibres, and a conſiderable portion or influx of the red blood itſelf; as we ſhall explain more at large, when we come to ſpeak of a muſcle. But all the foreſaid additions to the body are ſo far from being increaſed from old age, that, on the contrary, they diminiſh in it.

§. 254. But, moreover, the whole body, which is ſuppoſed to remain in a permanent ſtate, is really in a perpetual flux, and never at reſt. The change, which is made at the expence of vaſcular property, never ceaſes; for perpetually ſome veſſels go on to be effaced or cloſed up into ſolid filaments, according as the preſſures from weight, the force of the muſcles, or of the heart, continue to act more upon certain parts. Hence we obſerve, that thoſe parts of the body firſt grow rigid, which are oftener uſed or laboured in every artiſt. All the cellular plates likewiſe are continually condenſed or hardened, while the glue and nouriſhment itſelf become more dry and earthy. From hence proceeds that rigidity of the joints and bones ſo commonly obſervable in old people, the frequent change of their cartilages into a bony nature, with a hardneſs of all their ſoft parts, from a deficiency of the flexile glue, remarkable even in the cellular ſubſtance of the brain, heart and arteries, with a greater ſpecific gravity of their whole body, all its particular parts, even the cryſtalline lens itſelf not excepted.

§. 255. Laſtly, the glutinous, attractive and nouriſhing property of the juices themſelves, which belong to the human body, is diminiſhed by the frequent uſe and introduction of ſaline foods, inflammable or ſpirituous drinks, with errors and exceſſes in diet of all kinds; whence the blood and lymph, at length, degenerate into a friable, acrid and little gelatinous diſpoſition. This is proved from the ſlow conſolidation of wounds and fractures in old people, from the remarkable fætor of their breath and urine, from the increaſe of ſaline and diminution of watry parts, obſervable in their blood, and from the opacity or diſcolouration of ſuch juices, as were formerly colourleſs or pellucid.

§. 256. In the decline of life, therefore, the intervertebral ligaments, by degrees, grow dry, hard and oſſified; whence the ſpine loſes its rectitude by a contraction of the vertebræ towards each other forward, by which the height or ſtature of the body is leſſened: the tendons, having loſt a great part of their flexile glue, become very ſhining, hard and cartilaginous;

nous; and even the muſcular fibres themſelves by repeatedly preſſing out the blood and juices from their intermediate veſſels, change into a dry, tendinous, white nature: all the veſſels, and more eſpecially the arteries, indurate by driving out their watry juices, and frequently put on almoſt a bony conſiſtence, while the plates of the looſe cellular ſubſtance are contracted into a kind of hard membranes. Thus the excretory veſſels, being in all parts compreſſed, and the exhaling ducts or pores cloſed or beat together, an univerſal dryneſs enſues, while the neceſſary depurations of the blood are diminiſhed. From hence the rigidity of old people is increaſed, and their blood aſſumes a more dry earthy texture, ſo as to depoſite a true earthy matter, inſtead of a moiſt vapour, throughout the cellular fabric, in all parts of the body. The truth of this appears from the numerous inſtances of indurations, and bony incruſtations by an effuſion of this matter into the fabric of the arteries, membranes, upon the ſurfaces of moſt of the bones, eſpecially the vertebræ, and as we ſometimes perceive in the very ſofteſt parts throughout the whole body.

§. 257. In this manner is the way opened to a natural death, which comes on ſo ſoon as the heart, now callous and feeble, or nothing increaſed in ſtrength, ſinks under the load of all the increaſing reſiſtances. The lungs, now leſs pliable, oppoſe too great a reſiſtance to the right ventricle of the heart on one ſide, as on the other ſide, does the whole ſyſtem of the capillary arteries, which, indeed, in all ſtages of life, oppoſe many conſiderable reſiſtances to the heart (§. 160.) Thus the blood, gradually loſing of its motion, at length ſtops, and is more eſpecially collected on the right ſide of the heart, while the way through the lungs is ſhut up; 'till at length the pump-like engine, we call the heart, after a few ſtruggles or palpitations, becomes itſelf quieſcent under the load of ſtagnant blood, which now begins to thicken or turn grumous.

§. 258. The limits of this natural diſſolution, nature herſelf has fixed or appointed to all ſorts of animals; although her proportions therein are not yet ſufficiently known to us. Man, being an animal remarkable for his longævity, eaſily ſpins out a natural life to twice the length of that we obſerve in an ox or an horſe; ſince frequently he attains the age of an hundred years, and ſometimes that of an hundred and fifty. The feathered tribe, we know from certain experience, are naturally very long livers; and theſe are again exceeded by fiſh, which, being furniſhed with cartilages inſtead of bones, grow perpetually.

§. 259. Thus death appears to be abſolutely neceſſary and unavoidable from thoſe laws of nature, with which we are at preſent acquainted; only the bounds of it may be changed by a difference in the proportion of the heart to the other ſolids, by a variation in the powers digeſting the aliments, with the particular conſtitution or nature of the blood, and the heat of the external air. For the larger veſſels will inevitably compreſs the ſmaller, the glue will of courſe grow more denſe and hard, as its watry parts exhale, and from the ſame exhalation, nothing can hinder the cellular threads and plates from running into more powerful attractions and coheſions. Yet this rigeſcence of the ſolids may be, in ſome meaſure, retarded, and the dry acrid temperature of the blood and juices may be leſſened by a moderate courſe of life; not exerciſing our machine too much, either by motions of body or paſſions of mind, by living upon vegetable food and drink, and ſhunning exceſſes of all kinds, even of cold itſelf.

§. 260. But it may be queſtioned, whether we are to believe, that new veſſels and new parts may be generated in the human body, or be again reſtored? whether the regeneration of parts, cut off from the polype, ſea-nettles, moſt of the worm tribe, ſnails, and the renovation of the ſtomach each year in crabs, and the tails of lizards, &c. may be eſteemed ſufficient argument for ſuch a belief? to which add the reproduction of true bones in the place of thoſe loſt? whether we are to refer hither the natural reparation of the hairs, nails, feathers, &c. which are by no means inorganic? to which add the new fleſh generated in wounds, renovation of the ſkin, reproduction of the ſcrotum, the callus of bones, &c? the queſtion, indeed, appears difficult. It ſeems then a common privilege, that inſects, and particularly thoſe ſpecified, enjoy a very ſlow motion of their viſcid, glutinous juices, in a very ſimple fabric; whence the ſaid juices do not run out as in us, but, by attraction, gather and cohere with the reſt of the body. In man, the membranes we ſee formed in hydatids, the fleſh in wounds, and the callus which fills up broken bones, and even occupies the place of whole bones that have been loſt, are produced from the glutinous juices, compacted by the pulſation of the adjacent arteries, and are a continuation from the divided veſſels, or a production of the extremities of the perioſtium within the wound. But we ſee, from the reunion and growth of parts cut off and ſewed on again, as in the noſe and lips, or only replaced, as in the teeth, that there is a natural neceſſity for divided veſſels to unite and cloſe with oppoſite veſſels divided. But for any of the more complex, large and organical members to be reproduced, is a thing unheard of; nor can it be admitted in the human body, which has ſo great a force of the heart, ſuch a putreſcent diſpoſition in the ſtagnant juices, and ſuch a complexity of fabricature in all its parts, very different from the ſimplicity nature obſerves in the formentioned inſects.

REMARK.

However unknown to us may be the intrinſic fabric, number and affections of the particles, pores and interſtices in the leaſt fibres, membranes and veſſels, 'tis certain, that in the human body, as well as in vegetable and foſſile, mixed and text bodies, they have a power of affinity, by which they ſelect certain particles from the common incrementive fluid, and then combine, apply and change them, ſo as to become part of themſelves; and this in a moſt regular geometrical fabricature, according to the laws of affinity and mutual attraction or appulſe given to the parts of matter by its creator. How regular and conſtant, in their figure and combination of parts, are the cryſtalizing ſalts, the mixed and text foſſils, ſtones and ſhells, from this principle merely. This power, though it be not abſent in vegetables, is yet governed by, and dependent on the force of an organic or tubular attraction and temporary impulſions from the air, heat, &c. So likewiſe in animals, the tubular and corpuſcular forces are modulated by centrifugal impulſion through diſtractile canals; joined with external reſiſtances from confining, but extenſible integuments. Each of theſe powers have their limits and proportions reſpectively one to another towards a natural, healthy organization and fabricature; and in the human body are ſubject to ſo many and different termina, in the ſcale of combination, from the more ſimple to the more complex organs, as profuſe volumes and languages ariſe from a few letters; that it is equally impoſſible as unneceſſary, to ſum them up by all the powers of algebra and geometry conjunctly. If particles of ſalts and other foſſils have an intrinſic power, by which they accede, concrete, and build up a regular texture; why may not the ſame corpuſcular affinity join with tubular attraction, and hygraulic vaſcular impulſe, to build up a regular organization, or even to increaſe or maintain it when ſo built. Theſe powers in the human body ſeem to be engrafted one upon the other: ſo that where vaſcular impulſion ends, there tubular attraction begins; and where that ends, corpuſcular affinity takes place, but in ſuch a manner, that they always operate conjunctly to the ſame end, though they may have different proportions in different parts;

ſo, we may ſay, the hairs, like ruſhes, vegetate by impulſion, or that the enamel of the teeth petrefies by vegetation. From all which we conclude, that organization, as well as nutrition, are ultimately finiſhed by that corpuſcular affinity, which is more remarkably conſpicuous in the accretion of mixed and text bodies, joined, however, with tubular attraction and vaſcular impulſion from the heart.

§. 261. We have hitherto conſidered what belongs in common to all the veſſels of the human body in general; it, therefore, now remains for us to go on to thoſe offices which belong to each artery in particular. Accordingly we chuſe to ſpeak firſt of the pulmonary artery, as well becauſe it firſt goes out of the heart from its right ventricle, as becauſe the aorta itſelf receives nothing but what firſt comes to it through that artery (§ 107.): but then to underſtand the uſes of the pulmonary artery, requires a previous deſcription of the lungs, as the organs of reſpiration, to which, therefore, we proceed.

LECTURE X.

Of reſpiration.

§. 262. THE bags of the pleura (§. 75, 76.) are exactly filled by the *lungs*; for ſo we call the two viſcera, which are diſtinguiſhed into right and left, in figure anſwerable to that of the bags themſelves which they fill, having a broad baſis below; they are terminated above at the firſt rib, by an obtuſe point or cone. The anterior face of them is flat, their ſides convex or round, internally or in their middle concave, forming a concavity ſufficient to contain the heart. The right lung is larger than the left, and more frequently divided, or half cut through, into three diſtinct lobes or portions; but the left lung is not ſo often divided into three. They are freely ſuſpended by the great blood veſſels, at liberty on all ſides, excepting where the external membrane of the pleura, departing from the thorax to the lungs, and to the diaphragm, forms there a mediaſtinal ligament. Betwixt the lungs and pleura is found a watry, or rather ſerous vapour, of a coagulable nature, like that of the pericardium (§. 80.), which vapour tranſudes from the ſurface of the lungs, and is ſometimes increaſed to a dropſy, or elſe concreting into fibres, joins the lungs to the pleura.

§. 263. The external membrane of the lungs is a ſimple, thin continuation of the pleura, ſpread all over them, from the adheſion of the great blood veſſels of the heart, yet ſo as to be capable of retaining wind eaſily without breaking, after being ſeparated from the lungs. The ſame membrane covers the interſtice or mediaſtinum of the lungs, like a bridge.

§. 264. The ſtructure of the lungs is a heap of lobes ſeparated from each other by intermediate intervals, in which is extended a looſe cellular ſubſtance; the firſt diviſion of them is into two extreme lobes, which are larger, and one middle one, which is leſs, yet cohering together, although afterwards they are again ſubdivided internally through a long ſeries into leſſer lobules down to the leaſt, 'till at laſt the ſmall lobules terminate in very ſmall cellular membranes, which, in adults, are variouſly figured and full of air, which paſſes freely on all ſides from one cell to another, by their open communications. Theſe veſicles of the lungs, therefore, do not receive the air by a ſingle orifice from the wind-pipe, as into an an oval grape or vial, but the air exhaling from the leaſt branches of the ſaid wind-artery, is admitted in ſuch a manner into their irregular ſpaces, that it freely ſpreads through them, from any one part of the lungs into all the reſt, and returns again in like manner. This is demonſtrated by inflation, which drives the air even through the leaſt branches of the wind-pipe into the ſmalleſt lobes; from whence it readily paſſes into all the reſt. Nor is the cellular fabric of the intervals ſhut up from the veſicles of the lungs, nor are the leſſer lobes ſurrounded by any peculiar membrane.

§. 265. The air is drove into theſe veſicles through the wind-pipe, which ariſes from the larynx (hereafter to be deſcribed), and from that only receives its air. The firſt part of this wind-pipe is ſingle, and deſcends along the ſmooth bodies of the vertebræ of the neck, partly fleſhy and partly cartilaginous, having the gula or æſophagus behind, and a little to the left of it; namely, within the cellular ſubſtance that ſurrounds the wind-pipe, follows a canal, made up by a ſucceſſion of cartilaginous and muſcular rings: theſe are thin and elaſtic, flatter and thicker in their foremoſt part, but thinner in their poſterior extremities, which are conjoined together by ſtrong tranſverſe muſcular fibres, which adhering firmly to each extremity of the cartilage, compleat the circle. But the lowermoſt bronchal cartilages, within the ſubſtance of the lungs, are compleat rings, leſſening in their ſizes.

§. 266. The muſcular or fleſhy rings, alternately placed with the cartilaginous ones, are made up of red muſcular fibres. Some of theſe are tranſverſe, connecting the detached ends of the annular cartilages, others deſcend from each upper to the next lower ring. But other muſcular fibres again deſcend perpendicularly behind from the cricoide cartilage, and having reached below the firſt diviſion of the bronchia, vaniſh within the lungs. The tranſverſe fibres contract or leſſen the diameter of the wind-pipe, as the longitudinal ones render it ſhorter. Alſo within the lungs, betwixt the imperfect rings, is found a ſort of muſcular fabric, but leſs uniform.

§. 267. In the cellular coat, which ſurrounds the muſcular one, but eſpecially in the back part of it, along the poſterior interval, that is betwixt the cartilages, are placed numberleſs ſimple glands, which open by very ſmall ducts, like pores into the cavity of the wind-pipe; by which pores they depoſite a watry and pellucid mucus into that cavity; which mucus, being without the leaſt acrimony, not hardening into a ſcaly ſubſtance, is of the greateſt uſe in defending theſe moſt ſenſible membranes from being injured by an impure air, full of particles, which, by their mechanical figure or chemical acrimony, might be very troubleſome. Laſtly, the internal tube of the wind-pipe is compleated or lined by a membrane, which is continuous with that of the mouth, ſmooth, ſoft and very irritable.

§. 268. The veſſels of this part of the whole wind-pipe in the neck, come from thoſe of the lower thyreoids; in the thorax, from other ſmall branches of the ſubclavian trunks or the mammaries, or the bronchials, properly ſo called. Small nerves to it are numerous from the recurrent and intercoſtal.

§. 269. In the upper part of the thorax, the wind-pipe is divided into two ſimilar branches reſembling the trunk itſelf, and formed like that of imperfect cartilages, alſo furniſhed with ſimilar glandules; each of which branches enters the lung to which it correſponds, only the right is ſomething ſhorter than the left. Having entered the lungs, the cartilaginous rings change into fragments, which become more and more difform and teſſalated, or angular, intermixed with the membrane of the pleura, 'till, at length, the cartilages decreaſing, terminate the laſt branches of the bronchia into mere membranes. The glandules here are like thoſe before mentioned (§. 267.) But there are other conglobate glandules of the lymphatic kind (§. 183.) placed at the diviſion of the branches, and upon the trunk of the wind-pipe, and about the lungs; but theſe are not of uſe to the wind-pipe.

§. 270. The laſt branches of the wind-pipe are inviſible, which exhale the air into the cellular ſpaces of adult lungs, and likewiſe receive the watry vapours exhaling from the arteries into the ſaid ſpaces; from whence they are thrown out by expiration.

§. 271. The blood veſſels of the bronchia are the *arteriæ & venæ bronchiales*; the former are almoſt conſtantly two, one coming from the upper intercoſtal of the aorta, which is diſtributed either to the right only, or to both the lungs; the other, from the trunk of the aorta itſelf, goes to the left lung. Sometimes there are more than two bronchial arteries to be ſeen; as when there are three, by the addition of a ſecond from the aorta. But ſometimes again there is only one artery in common. The bronchial veins are moſt commonly two, one right from the vena azygos, the other left from a peculiar branch of the ſubclavian vein. Theſe blood veſſels travel together with the branches of the wind-pipe, and deſcend into their membranes in ſuch a manner, that the pulmonary arteries, in their way, inoſculate with their contiguous arteries, as the veins likewiſe communicate with each other. There are ſome inſtances where the pulmonary vein itſelf has given ſmall branches to the lungs, to the wind-pipe, and particularly to the ſurface of the lungs.

§. 272. But there are other larger veſſels belonging to the lungs, called the pulmonary artery (deſcribed §. 100 and 102), and the pulmonary vein (§. 104.). The trunks of theſe blood veſſels likewiſe accompany the branches of the wind-pipe in their courſe through the lungs, ſurrounded with a good deal of cellular ſubſtance, which ſubſtance, being increaſed, compoſes the ultimate ſpungy fabric of the lungs themſelves. Within this cellular fabric, and likewiſe upon the ultimate ſpaces or cells, the air veſſels and blood veſſels are ſubdivided, ſpread and interwove ſomewhat like the meſhes of a net; and here the ſmall arteries (§. 261.) exhale a plentiful vapour into their cells, and the veins abſorb a watry vapour from the ſame cells. Hence water tinctured, the whey of milk, or a thin waxen injection, being urged into the pulmonary artery, flows with a froth into the wind-pipe; or on the contrary, being urged from the wind-pipe into the lungs, they penetrate into the pulmonary artery. In like manner, injections paſs from the pulmonary vein into the wind-pipe, or from thence again, they may be forced into the veins. Laſtly, a liquor, injected by the arteries, readily enters the pulmonary veins, and the reverſe.

§. 273. The lymphatic veſſels, as in other parts, form a net-work upon the ſurface of the lungs, from whence there are branches conveying the lymph to the cavity at the back part of the mediaſtinum, and to the ſmall glands, which lie behind the æſophagus, opening, at laſt, into the thoracic duct. The pulmonary nerves are ſmall, from a nerve of the eighth pair, which deſcends and ſubdivides according to the courſe of the bronchia. There are alſo ſome ſmall nerves to the lungs from the recurrent, and likewiſe from the cardiac plexus, which enter together with the large blood veſſels.

§. 274. The quantity of blood, which enters into the lungs, is exceeding great, equal to (or even perhaps greater than) that which is ſent in the ſame time throughout the reſt of the whole body; which, therefore, demonſtrates ſome very conſiderable uſe, proper to this viſcus. And that this uſe depends manifeſtly upon the air, appears from the univerſal conſent of nature, in which we ſcarce find any animal without breathing; alſo from the ſtructure of the lungs in the fœtus, in which, for want of air, they are uſeleſs, receiving only a ſmall portion of the blood, which the pulmonary artery conducts from the heart. We are now, therefore, to ſpeak of reſpiration, by which the air is drawn into, and expelled from the lungs.

§. 275. The element of air appears from the principles of philoſophy, to be an elaſtic, inviſible and ſonorous fluid. But the atmoſpherical air, which we commonly receive into the lungs, is impure, filled with a great quantity of watry vapours, with the ſeeds of plants and animals, and other foreign matters, but in very minute particles; ſo that it weighs 850 times leſs than water. This air, which ſurrounds the earth on all ſides, being preſſed by the incumbent columns of its own maſs, perpendicularly, laterally and in all directions, enters, wherever it meets a leſs reſiſtance, and with a conſiderable force, as appears from experiments made with empty or exhauſted veſſels, and by the air-pump.

§. 276. This air is excluded from all parts of the human body by the ſurrounding cloſe ſkin, which, even when dried or tanned, is impervious to the air; but more ſo as under the ſkin is placed the fat, making an equal reſiſtance to the narrow openings of the abſorbing veſſels. It, therefore, now remains for us to enquire, why the air enters the lungs of an adult perſon; for with this they are, in a manner, conſtantly full, and of courſe are equally preſſed, and reſiſting againſt the weight of the whole atmoſphere: but that the lungs always contain air is evident, becauſe, however cloſe you compreſs them, they will be ſtill lighter than water; and even in the fœtus, after they have been inflated but a few times, they always ſwim, whereas, before breathing, they ſink to the bottom of water, if they have as yet not given admittance to the air.

§. 277. The equilibrium of the air's preſſure being removed in any place, it conſtantly deſcends or flows that way, where it is leaſt reſiſted (§. 275.). Therefore, for the air to enter the lungs, they muſt make a leſs reſiſtance to it than before; namely, the air, which is already in the cellular fabric of the lungs, muſt be rarified; but this effect will follow, if the cavity of the thorax, in which the lungs are contained, and which they exactly fill, be dilated (§. 284.). Thus the air, which is always in the lungs, expands into a larger ſpace, by which, being weakened in its ſpring, it makes a leſs reſiſtance to the external air; and conſequently a portion of the ſaid external air deſcends into the lungs, ſufficient to reſtore the confined and rarefied air, filling the lungs to the ſame denſity with that of the external air. See §. 290 and 293.

§. 278. We muſt, therefore, deſcribe the powers, which dilate the thorax to produce this effect. The breaſt or *thorax* is a ſort of craticle or cage made up of moving bones, muſcles and cartilages; being of a figure almoſt elliptical or oval with the narrower end of the obtuſe cone upwards, and ſomewhat compreſſed before, but behind divided by an intermediate eminence of the ſpine. In the upper and lateral parts of this bony craticle are placed the lungs; in the middle and lower part of theſe lies the pericardium and heart;

after

after which, a portion of the arched baſis is taken up by ſome of the abdominal viſcera.

§. 279. The ſhell and pediment of the thorax are compoſed by twelve ribs on each ſide, with the ſternum before, and the ſpinal vertebræ in their middle behind. The firmneſs of theſe vertebræ, as well from their being locked by proceſſes into each other, as by their connexion with the ribs, makes their union not eaſily diſſolvable, but very ſufficient to ſupport the ribs, as upon a ſolid baſis. The *ribs* are in general bent in the form of an irregular arch, having their greateſt curvature in the ſides of their back part, but extending thence in their fore part towards a right line. The bones of the ribs lie ſufficiently parallel with each other. The greater part of the rib, which is bony, is round and thick backward, but thin and flat forward; while the other part forward is completed by a cartilage, which, in general, continues the figure of the rib, in a flat broad concavity of whoſe bony extremity it is fixed and grows from.

§. 280. The poſterior and bony thick part of each rib terminates in a head, along from which, in the body of the uppermoſt and two lowermoſt ribs, runs a cavity or groove, formed in the other ribs betwixt every two adjacent margins, which lie one towards the other. The vertebræ are tied to the ribs by ſtrong ligaments, of which the principal ſpread from each rib like rays into the next adjacent vertebræ, other ligaments tie the tranſverſe proceſs to the tubercle of the rib, and others tie the ribs one to another and to the tranſverſe proceſſes likewiſe at the ſame time. Moreover, betwixt the angle of incurvation and the juncture with the vertebræ, each of the ten upper ribs ſend out a protuberance, which, being articulated with the plain ſide of the tranſverſe proceſs of each vertebra, are ſo tied by ſhort and ſtrong ligaments to that proceſs, that the rib has liberty to make a ſmall aſcending and deſcending motion, but with a conſiderable degree of firmneſs.

§. 281. Among the anterior cartilages of the ribs, the ſeven uppermoſt reach to the ſternum, and enter into ſmall notches or cavities, which are incruſted with a cartilage in the ſides of that bone, to which they are alſo made faſt by ſtellated ligaments. Of the five remaining ribs, the uppermoſt is faſtened to the ſeventh preceding, and that to the next lower by peculiar productions of the cartilage, firmly cemented with its fellow, and covered with a ſtrong cellular membrane, by which they form a continuous margin or extremity, which is, at laſt, alſo faſtened to the ſternum; but in the twelve lowermoſt ribs they are at liberty or detached, adhering only to the muſcles on each ſide. Theſe cartilages of the lower ribs are connected by ſtrong ligaments to each other and to the ſternum.

§. 282. The courſe or direction of the upper rib is deſcending, but the ſecond rib joins the ſternum almoſt in a right angle, while the others aſcend from the ſpinal vertebræ, but more eſpecially raiſe upwards, as they come nearer towards the ſternum. But the bony part of the ribs is placed in ſuch a direction, that the uppermoſt have their ſides in the fore part, very much declined forward almoſt tranſverſely; the next or ſecond ribs are placed almoſt to a perpendicular, while the middle ones in their lower part project a little outward or forward. Therefore the firmneſs of the ribs varies, the uppermoſt being ſhort rather grow into the ſternum than form a joint with it; and they tranſverſely reſiſt it with a conſiderable ſtrength on each ſide. From thence the mobility of the ſternum increaſes downwards, 'till its bottom, adhering only to muſcles, has the moſt eaſy motion.

§. 283. The ſternum, in general, is a thin ſpungy bone altogether, one in adults, but is variouſly divided into ſeveral in the fœtus and younger ſubjects. Its upper end reſembles an octogon, at the broader part of which it is articulated with the clavicles, which are jointed very cloſely with the triangular head of the ſternum, and with the firſt rib on each ſide. The ſides of the ſternum receive the extremities of the ribs, each into their reſpective angular cavities, while the lower part of the ſternum terminates in a detached bony appendix, which is, in part, cartilaginous, capable of moving and changing its poſition under the denomination of the Enſiform cartilage.

§. 284. In order, therefore, to rarefy the internal air, that the external might ruſh into the lungs, it was neceſſary for the thorax to be dilated. For thus all the ſections of the thorax form right angles, and its capacity is increaſed. This motion is performed by various muſcles, which either operate conſtantly, or only at certain times. The intercoſtal muſcles, therefore, all of them act perpetually in elevating the ribs. For, by this name, we underſtand twenty-two muſcles, of which, eleven are external or next the ſkin, and as many internal, ſeparated from the pleura only by fat or cellular ſubſtance. The beginning of the *outer intercoſtals* is at the poſterior articulation of the ribs (§. 280.); but the termination of them is in the anterior bony part of each rib, at ſome diſtance from the cartilage, in ſuch a manner, that the remaining ſpace betwixt the cartilage and ſternum to the muſcle is filled by a tendinous expanſion. The courſe or direction of theſe muſcles is ſuch, that the fibres deſcend obliquely forward, from the lower edge of the upper rib to the upper edge of the lower rib. And that their action is to elevate the ribs, all authors unanimouſly agree; becauſe they thus deſcend from the upper leſs moveable to the lower more eaſily moveable bone, in ſuch a manner, that their lower point lies more diſtant or remote from the hypomochlion or point of motion, which is in the coſtal articulation with the vertebræ, conſidering the rib as a lever.

§. 285. But the *internal intercoſtals* ariſe at ſome diſtance from the vertebræ, almoſt at the outer tubercles of the ribs before-mentioned (§. 280.); from whence their origination continues as far as the ſternum, into which the uppermoſt of theſe muſcles are inſerted above. The direction of theſe is contrary to that of the former, except the anterior part of the firſt or uppermoſt of them; ſo that they deſcend from the lower margin of the upper rib backward, to the upper edge of the lower rib forwards. Therefore ſome doubt of their action, becauſe their lower part is inſerted into that portion of the rib, whicſt is neareſt its articulation with the vertebra, and which, therefore, ſeems to be the leaſt moveable: However, they elevate the ribs, notwithſtanding this; for the great firmneſs or immobility of the upper rib, exceeding that of the lower, is evident from the articulation, weight, and ligaments there formed, which ſurpaſſes that mobility, ariſing from the greater diſtance of the center of motion: this appears from the diſſection of living animals, in which we ſee the inner intercoſtal muſcles operate in the elevation of the ribs, and reſt in the depreſſion of them; alſo from a flexible thread fixed to the rib of ſome human ſkeleton, and drawn in the ſame direction with that of the fibres of the inner intercoſtal muſcles, by which means the lower rib will be always approximated towards the upper: the greater firmneſs alſo of the upper ribs proves this, as they ſerve for a fixed point to the lower ones; for the firſt or uppermoſt ribs are from eight to twelve times firmer and leſs moveable than the lower true ribs; but the difference of diſtance in them, from the center of motion, is ſcarcely the twentieth part of the length of their whole lever. [Laſtly, the elevating power of the internal intercoſtal muſcles appears plainly by experiment in a dead ſubject, whoſe thorax, being raiſed or inflated, thoſe muſcles ſwell or contract.]

§. 286. By the action, therefore, of theſe muſcles, the thorax is elevated; ſince as the ribs turn upon their articulations, their extremities thereby deſcend and form larger angles; but from thence in the middle of their arches, by aſcending, their lower edges are drawn upward. At the ſame time, the ſternum is thruſt out forward more from the vertebræ and from the ribs. Thus the ribs recede farther from the vertebræ, the right ribs depart from the left, and the diameter on all ſides, betwixt the right and left ribs, betwixt the ſternum and the vertebræ, is every way increaſed to about two lines or twelfths of an inch: and therefore this enlargement, following in every imaginable ſection of the thorax, will ſufficiently dilate the cavity of the breaſt. This action of the ribs is more particularly complete in women, and in men who have no ſhortneſs of breath. But this dilatation alone is not ſufficient for healthy breathing, nor is it ſo conſpicuous or evident in men, although, in them, the intercoſtal muſcles, by retaining and elevating the ribs, very much aſſiſt the inſpiration in a tacit or unactive manner, while they afford a fixed point to the diaphragm, that the whole force of that muſcle may be ſpent not ſo much in depreſſing the ribs, as in urging down the abdomen. The bigger part, therefore, of the

ſpace,

ſpace, which the thorax gains in inſpiration, ariſes from the action of the diaphragm.

§. 287. By *the diaphragm* we underſtand, a muſcle, expanded in a lenticular or ſmall oven-like curvature, by which, in general, the pulmonary bags are parted off tranſverſely from the abdomen, in ſuch a manner, that the middle of the ſeptum is nearly the higheſt or uppermoſt part of its convexity, by which it ſupports the pericardium, while its lateral parts, which ariſe from the ſides of the thorax and loins, have on all ſides a deſcending obliquity, but the moſt backward, as it deſcends loweſt of all at the ſpine. The fleſhy portions of this muſcle ariſe before from the inner ſide of the enſiform cartilage, and from the inner face and extremity of the ſeventh, eighth, ninth, tenth, eleventh and twelfth rib; after which follows an interval, in which the naked pleura lies contiguous to the peritonæum; from thence the muſcular legs or appendices of the diaphragm, which are much the ſtrongeſt part of it, being collected on each ſide into two, three or four round muſcular portions, ariſe fleſhy from the tranſverſe proceſs on each ſide of the firſt and ſecond vertebræ of the loins, and tendinous from the middle of the body of the ſecond, third and fourth of thoſe lumbal vertebræ.

§. 288. All the fore-mentioned muſcular fibres, (§. 287.) becoming tendinous, form the center of the diaphragm, which reſembles, in figure, an obtuſe index of a ſun-dial, having the middle of the larger angle ſupporting the diaphragm, while the lateral angles or wings deſcend backward, the left being narrower than the right. This center of the diaphragm is more moveable and at liberty than the reſt; except in the middle of its tendinous part, near the fleſhy margin, where the incumbent heart makes a reſiſtance, but the lateral parts and the fleſhy portions belonging to them, are the moſt moveable.

§. 289. There are two conſiderable openings through the diaphragm, of which that on the right ſide of its tendinous part is ſomewhat ſquare and lined or circumſcribed by four ſtrong tendinous portions; the left opening is elliptical betwixt the two muſcular legs, or right and left portions, which ariſe from the middle of the bodies of the vertebræ of the loins, under which opening they decuſſate and croſs each other once or twice, but above they end in the tendon. This left opening is, therefore, drawn cloſe together in the contraction of the diaphragm, while it is probable, that the other opening remains immoveable; becauſe the tendons of muſcles are but little changed in their motion of contraction.

§. 290. The ſtructure of the parts, and the diſſection of living animals demonſtrate, that the fleſhy portions of the diaphragm, which on all ſides aſcend from the firm parts to the middle and more moveable portion of it, do, by their contraction, depreſs the ſame, and by that means draw downward the lateral bags of the thorax, which contain the lungs (§. 75.): and by this means the perpendicular diameter of the thorax is conſiderably increaſed, while all the viſcera of the abdomen are compreſſed and urged againſt the reſiſting muſcles of the abdomen, with the reſiſting bony ſides of the pelvis. So that the diaphragm almoſt alone performs the office of reſpiration in a healthy man, who is at reſt. [The lungs themſelves are altogether paſſive or obedient to the action of the air, ribs and diaphragm; to which they are preſſed into ſuch cloſe contact on all ſides, that when the thorax is denudated or cleared by the knife, leaving its capacity entire, the lungs appear filling out the pellucid pleura and diaphragm, as cloſe as an onion to its withered ſkins.]

§. 291. But in larger inſpirations, which receive a greater quantity of blood driven into the lungs, and when there is any obſtacle or difficulty oppoſed to the action of the lungs themſelves; in thoſe caſes, ſeveral other powers conſpire to dilate the breaſt and raiſe the ribs: which powers are inſerted either into the thorax, clavicles or ſcapulæ, ſuch as the ſcaleni muſcles, trapezii, cervicales deſcendentes, ſerrati ſuperiores, and pectorales, together with the ſmall elevators, of which a more ample deſcription may be had from profeſſed ſyſtems of anatomy.

§. 292. We have hitherto ſurveyed the powers (§. 209, 286.), which are able to increaſe the capacity of the thorax in all its dimenſions; it, therefore, remains, that the air (§. 275.), which is a heavy fluid, and preſſed on all ſides by the incumbent columns of the atmoſphere, muſt now enter the thorax or lungs by that greater force which it has over the little rarefied air already in the lungs, or yet more powerfully, if they contain no air at all. In this action, therefore, which is called inſpiration, the bronchia or branches of the wind-pipe are every way increaſed, both in length and diameter; becauſe all the diameters of the thorax are increaſed: but in this act, the inflated lungs always follow cloſely contiguous to the pleura, without leaving any intermediate ſpace. At the ſame time the pulmonary blood-veſſels, which are wrapped up, together with the bronchia, in a covering of the cellular ſubſtance, are likewiſe with them extended in length, and ſpread out from ſmaller into larger angles, by which means the circulation is rendered eaſier through them. While this is performing, the veſicular ſubſtance, or fleſh of the lungs themſelves, filled out with air, increaſes thoſe ſpaces through which the capillary blood-veſſels of the lungs make their progreſs, whereby the veſicular preſſure, upon each other, and upon thoſe veſſels adjacent, is leſſened; thus, therefore, the blood will flow with greater eaſe and celerity into and through the larger and ſmaller veſſels of the lungs. Hence, we obſerve, the pulſe is quicker, during the time of inſpiration. But as for the preſſure of the air upon the blood in the lungs in this action, it is ſo inconſiderable, as not to deſerve our notice. [For the preſſure of the atmoſphere is never naturally ſo much increaſed, as to urge the air through the pores of the lungs into the blood, as it eaſily may be forced by art with a ſyringe; although ſome of the air may be ſubſtantially expelled or abſorbed this way, as it is in common, through the pores of all other bodies, while it approaches to a ſolid or fixed ſtate.]

§. 293. It is by ſome queried, whether there be not air betwixt the lungs and the thorax? and whether this air, being rarefied in inſpiration, is not afterwards condenſed, ſo as to compreſs the lungs, and cauſe inſpiration? and they again aſk, whether this opinion be not confirmed by the inſtances of birds, in which we find this matter to be truly ſo. But we ſee every thing concurs to confute this opinion: for (1.) immediately behind the pleura, in living quadrupeds, as well as in dead human bodies, the lungs are contiguouſly viſible to the naked eye, without any intermediate ſpace betwixt them (§. 290.); but the pleura being perforated, the lungs are immediately, by the contiguous air that enters, preſſed together towards the vertebræ. (2.) Large wounds, admitting the air only into one cavity of the thorax, diminiſh the reſpiration; but ſuch wounds, as let the air into both cavities, quite ſuffocate or ſuppreſs the reſpiration. (3.) The thorax being opened under water, ſends out no bubbles of air through the ſaid water. Again, (4.) the imaginable ſpace betwixt the lungs and the thorax is always filled up by a watry or ſerous vapour, or elſe, by the ſame vapour, condenſed into a watry lymph. (5.) If the lungs adhere, they injure the reſpiration but in a ſmall degree; which ought entirely to ceaſe, if it required an intermediate air betwixt the lungs and thorax. Finally, (6.) the external air, being admitted to any of the internal membranes of the human body, deſtroys their texture, if they are not defended by a plentiful mucus; of which we can find none, either upon the ſurface of the lungs or of the pleura.

§. 294. After the thorax has been every way dilated by the ſaid powers (§. 290, 286.), as far as it well can be, or as far as is ſufficient for the purpoſes of life and health, the air, thus received into a place conſtantly near thirty degrees hotter than itſelf, grows warm there from the blood, [for the middle degree of the air's heat, in the northern countries of Europe, mounts the thermometer to about 48 gr. while the mean heat of the expired air from the lungs is 94 gr. of which the difference 46 gr. of heat is gained by the air from the blood, ſince breath ſeems to have the ſame heat with the lungs in its contact] from which it acquires about fifteen degrees of heat; therefore the air thus expanding the cells to their utmoſt extent, whoſe dilatation, at the ſame time, meets with no empty ſpace in the thorax, the blood thereupon begins to be ſtopt by the air's expanſion [being rarefied or increaſed one twelfth part of its bulk] compreſſing the leaſt veſſels, by which means a new reſiſtance ariſes to the blood, perpetually flowing from the heart into the lungs; and, therefore, we ſee, in hard ſtraining and long retenſions of the breath, the venal blood ſtagnates in the veins (eſpecially about the head) before the right ſide of the heart, which is now ſhut, becauſe unable to empty itſelf into the lungs; whereupon the face ſwells or looks red, and ſometimes the veins of the brain, neck, inteſtines, kidneys, lungs, or even the right auricle itſelf, will be burſtened by the violence. Such is the cauſe of death, in thoſe who are ſuffocated by compreſſed air, by drowning in water, or by ſtrangling with cords. Therefore that anguiſh or uneaſineſs, which ariſes from the ſtoppage of the blood in its courſe through the lungs of a healthy perſon, is the occaſion which excites him to open or relax again the powers of inſpiration, and immediately to ſtir up the forces which concur to expiration, thereby to free the thorax and lungs from the too much rarefied air.

§. 295. The powers concerned in expiration are chiefly the oblique muſcles of the abdomen, together with the ſtrait and tranſverſe ones. The former of theſe are, in one part of them, faſtened to the lower ribs, and, in another part, they are attached to the os pubis and ilium, as a fixed point, with reſpect to the breaſt. Therefore the ſtrait muſcles, being contracted, depreſs the arch or convexity into which the abdominal viſcera are thruſt by the diaphragm, and bring the ſame nearer to a ſtrait line; and, at the ſame time, the abdominal viſcera are preſſed by thoſe muſcles upward and backward againſt the diaphragm, which alone is able to give way, and yield up into the thorax, which, at that time, is rendered ſhorter. The oblique muſcles, for the ſame reaſons, compreſs the lateral parts of the abdomen, and urge the liver, ſpleen and ſtomach upwards: and laſtly, they draw down the ribs, which were before elevated by the intercoſtals. The tranſverſe muſcles, indeed, do not draw down the ribs, but they pull the cartilages of the falſe ribs a little inward, and render the whole capacity of the abdomen leſs, while, at the ſame time, they urge the viſcera againſt the diaphragm. By theſe means the thorax, contrary to its former ſtate (§. 286.) is every way rendered narrower and ſhorter, ſo as to expel as much air out of the lungs, as is ſufficient to relieve the uneaſineſs caus'd by its retention (§. 294.). At the ſame time the muſcular fabric of the bronchia exerts a power of contraction againſt the diſtending air, ſo as to promote its expulſion; and the ribs themſelves likewiſe returning by their elaſticity to that ſituation and reſt, which their articulations require in a ſtate of expiration, do all of them fly upwards and together, ſo ſoon as the extending powers ceaſe; whereupon their elaſticity reſtores them ſpontaneouſly to their reſpective places during expiration. From hence expiration becomes eaſier than inſpiration, and quicker in proportion as three to two; and from hence it remains always as the laſt act in a dying perſon. The triangular muſcle alſo of the ſternum, by elevating the cartilages of the true ribs, together with the ſternum itſelf, which they draw upward and backward, has ſome ſmall ſhare in this action.

§. 296. In a more powerful reſpiration, when the inſpirations are made wilfully greater, the expirations are likewiſe increaſed by the aſſiſtance of ſome other powers, as of the ſacro lumbalis, longiſſimus and quadratus muſcles of the back and loins. This force, by which the air is blown out of the lungs through a tube, is ſufficient to carry a leaden bullet, weighing above a dram, to the diſtance of one hundred and ſixty yards. But in a healthy perſon, the muſcles of the abdomen alone ſuffice to an eaſy expiration, in which the lungs are not ſo much emptied of air as they are by a violent efflation..

§. 297. The effects of expiration are a compreſſure of the blood veſſels in the lungs, a reduction of the bronchia or branches of the wind-artery into more acute angles, a preſſure of the reticular ſmall veſſels by the weight and contact of the adjacent larger veſſels; by which means part of the blood, heſitating in the capillary arteries, is urged forward through the veins to the left ſide of the heart, while, at the ſame time, that part of the blood is reſiſted which flows in by the artery from the right ventricle; for we ſee, by experiment, that if the lungs are not inflated, they are never well filled by an injection, which always ſucceeds the beſt, by cauſing the lungs to imitate vital reſpiration. [Does not, therefore, the blood ſeem to flow quicker through the lungs, than through other parts of the body? and is not this made probable from the quantity of the blood, and the ſhortneſs of its courſe, in going from the right to the left ventricle?]

§. 298. In this manner a freſh neceſſity follows for repeating the reſpiration; becauſe the collapſed veſſels of the lungs reſiſt the blood, repeatedly expelled from the right ventricle of the heart. And this makes another cauſe of death, in thoſe animals which expire in veſſels exhauſted of air: for in ſuch, the lungs, having the air drawn out from them, appear denſe, ſolid and heavier than water; whence they are rendered impervious to the blood. Of the ſame kind is the death of thoſe who are extinguiſhed by lightening. Thus, therefore, by the power of a moſt wiſe fabricature, the organs of expiration are relaxed, ſo ſoon as that uneaſineſs is perceived, which ariſes from the hinderance of the blood's courſe through the lungs; and thereupon the powers of inſpiration are excited into action, whereby the courſe of the blood through the lungs is rendered free and quicker. [A denſe air will ſupport life much longer than that which is rarified; becauſe the former more eaſily and ſpontaneouſly enters and diſtends the lungs, while the latter, being unable to overcome the reſiſtance of the air-veſſels and confined breath, is excluded. Yet a healthy perſon can, without much difficulty, ſupport any air that has but half the common denſity of the atmoſphere.]

§. 299. It is by ſome queried, whether or no there are not other cauſes of alternate reſpiration? whether or no we may hope for any diſcovery in this matter, by compreſſing the vena azygos, the phrenic nerve, or intercepting the blood ſent to the brains? But thoſe are repugnant to comparative anatomy; by which we always find the ſame alternation in the breathing of the animal, independent of any ſuch nerve or vein. Whether or no reſpiration is from the alternate contraction of the antagoniſt muſcles, among which, thoſe of expiration relax the others of inſpiration, and the reverſe? but in this manner, all the muſcles of the human body are perpetually in an alternative motion.

§. 300. From what has been hitherto ſaid, it appears, that reſpiration is unavoidably and abſolutely neceſſary to life in a healthy adult perſon; becauſe, whether the lungs remain long in a ſtate either of expiration or inſpiration (§. 298, 293.), we ſee death will be the conſequence. Therefore no animal, that has lungs like ourſelves, after it has once breathed, can ſubſiſt longer than a few minutes without the uſe and benefit of a free air; but it will either periſh, or, at leaſt fall into ſuch a ſtate, as differs from death only in its being recoverable again by certain powers or actions.

§. 301. But the uſe of reſpiration is different from this neceſſity, which nature might have avoided, either by uſing no lungs at all, or elſe by diſpoſing them in a manner, reſembling thoſe of the fœtus. This uſe, therefore, of reſpiration muſt be very conſiderable, ſince all animals are either made with lungs, or with gills as in fiſh, or elſe with a wind-pipe diſperſed through all parts of the body, as in inſects.

§. 302. In order to diſcover this immediate uſefulneſs of reſpiration in mankind, let us compare the blood of an adult perſon to that of a fœtus, and alſo with the ſame vital fluid in fiſh. It appears then in a fœtus, that the blood is deſtitute of its florid redneſs and ſolid denſity; and in the blood of fiſh we obſerve, there is neither heat nor denſity, and but little craſſamentum contained in it; and, therefore, all theſe properties, we are, by the nature of things, perſuaded, the blood acquires in the lungs.

§. 303. It follows, therefore, that our blood acquires its heat principally in the lungs; for that all animals, which have lungs, and two ventricles in the heart, have the heat of their blood commonly twice that of the atmoſphere (§. 294.). [Thus, in the ſame northern ſeas, we obſerve, that thoſe fiſh, which have no lungs for breathing, are cold as the element, although their flight and motion through the waters be ever ſo ſtrong and rapid; but at the ſame time thoſe of the whale kind, which breathe with lungs, have their blood warm like that of man, although they remain almoſt ever ſleepy and ſluggiſh. Neither the heart, therefore, nor all the reſt of the body, are able to generate the heat of the blood, without the aſſiſtance of the lungs.] But does not this ariſe from the alternate extenſion and contraction, relaxation and compreſſion of the pulmonary veſſels (§. 292, 295.), by which the ſolid parts of the blood are perpetually rubbed together, and cloſely compreſſed in the attrition that is made during expiration, as it is more rapidly moved and ground together during inſpiration. Nor is it any objection to this, that water cannot be made to grow hot by any friction. Nor, in reality, is that aſſertion true; for water, by violent winds and motion, as well as milk, acquires ſome degree of warmth; and the blood, which is ſo much more elaſtic and inflammable than water, muſt of courſe acquire a much greater heat. Nor is the heat of the blood from any efferveſcence. For only the muſcular motion, being increaſed, or even merely by an increaſed uſe of the organs of reſpiration, the heat of the blood is augmented; as it is diminiſhed in proportion, as thoſe actions are diminiſhed, and ſoon ceaſes when they are wholly ſuppreſſed.

§. 304. The denſity of the blood is, indeed, again promoted in the lungs, partly by the copious diſcharge of the watry vapour, which is there ſeparated, and expelled from the pulmonary veſſels, by which the reſt of the maſs will become ſpecifically heavier. But the ſame effect ſeems to follow more eſpecially from the attrition and preſſure, which the blood here ſuffers in being alternately retarded, accelerated, and figured in its courſe through the modulating tubes of the leaſt veſſels, which give a ſphericity and denſity to the particles. And, in this reſpect, the pulmonary vein, being ſmaller than its correſponding artery, is of no ſmall uſe towards increaſing the attraction of coheſion betwixt the parts of the globules, ſo as to compreſs and bring them cloſer to each other. But it is well known, by the experiments of Sir Iſaac Newton, that redneſs is increaſed by a greater denſity of particles. From hence it is, that the redneſs, heat and denſity of the blood are always proportionably encreaſed together by muſcular motion or exerciſe, with which the motion of the lungs in reſpiration neceſſarily correſponds and increaſes. [But that there is ſome ſmall difference betwixt the blood of the lungs and that of other parts, is argued from many experiments; and particularly extreme cold there condenſes the blood in ſome degree. Add to this its difference from the thin, watry and light blood of fiſhes.]

§. 305. It is, therefore, queried by ſome, whether the air itſelf is not received by the blood in the lungs, ſo as to excite neceſſary vibrations therein? whether this does not appear from the reſiſtance of bodies to the heavy external air; and from the air found in the blood veſſels, in the cellular ſubſtance, and in certain cavities of the human body; alſo, from the cracking obſerved by an extenſion of the joints; to which add the air manifeſtly extravaſated from the wind-pipes into the hearts of certain animals, as in the locuſt, together with a neceſſity of a vital oſcillation in the blood itſelf? [and laſtly, the increaſed redneſs of the pulmonary blood?]

§. 306. Contrary to all this, it is evident, that the blood here receives no air into itſelf;

partly from the minuteneſs of the inhaling veſſels, with the mucus that perpetually lines the ſides of the veſicles in the lungs; to which add the nature of the elaſtic air itſelf, which is very unapt to paſs through capillary veſſels, with a repulſion of it by water, that hinders it from paſſing through paper, linnen cloth or ſkins that are wetted by water. Again the air being drove into the wind-pipe, never paſſes to the heart, or whenever it does, it is forced thither by ſome great or unnatural violence: but the permanent air in the veſſels and humours of the human body, from a ſtate of inelaſticity, may bcome elaſtic by putrefaction, froſt or an external vacuum. But ſuch permanent unelaſtic air is incorporated with all liquors, and taken into our bodies with the aliments and with abſorbed vapours, mixing ſlowly and with ſome difficulty. But there never were any elaſtic bubbles of air obſerved in the blood of a living animal; and ſuch air, being inflated into the blood veſſels of any living animal, kills it certainly and ſpeedily. [Nor is there any great certainty of the blood in the pulmonary veins, being of a brighter red colour.]

§. 307. Whether or no the blood is cooled in the lungs? and whether or no this ſeems to be true from the death of animals in air, which is hot to ſuch a degree, as equals the heat of the hotteſt breezes in the moſt ſultry dog-days? [and whether the pulmonary veins are not, therefore, leſs than the arteries?] that the blood is cooled in the lungs, is thus far true;

in that, it there communicates fifteen degrees of its warmth to the contiguous air (§. 294.). But that this was not the principal deſign of nature here, upon the blood, is evident; ſince no one will ſay, that the venal blood is hotter than the arterial, although ſome pronounce the former to be ſomewhat cooler. Since, therefore, the venal blood enters the lungs, if it be there cold, it will follow, that the arteries muſt receive it ſtill colder. But then here the degrees of heat, which the blood communicated to the air, are again recovered by it. [And, indeed, a perſon may live in an air much hotter than the blood itſelf. We ſee the greater capacity of the right ventricle and pulmonary artery was neceſſary to reſerve and retard the blood, as the pulmonary vein, being narrower, accelerates it.

§. 308. Whether the uſe of the lungs is to abſorb a nitre from the air to the blood? or whether the florid colour, obſervable in the ſurface of a cake of blood, be owing to the ſame cauſe, while the bottom part looks of a dark and blackiſh colour? remain as queſtions with ſome. That there is a kind of volatile acid in the air is certain, ſince that meeting with a ſuitable earth forms nitre; for a nitrous earth, being exhauſted of its ſalt, and expoſed again to the air, becomes re-impregnated with more nitre. But the ſame univerſal acid, we know by certain experiments, meeting with a different ſort of earth, forms a vitriolic ſalt, or elſe ſea-ſalt. For the caput mortuum of ſea-ſalt, which remains after the diſtillation of the ſpirit, recovers ſo much ſtrength from the air, as enables it to yield more ſpirit by diſtillation; even in ſnow there is a cubical ſalt, but marcaſite ſweats out a true vitriol, and colcothar recovers again the acid ſpirit, which was drawn from it; alſo fixed alcali, expoſed to the air, turns into a vitriolic tartar. This, therefore, cannot be the uſe of reſpiration, becauſe thoſe ſalts abound in too ſmall a quantity in the air for ſuch uſes; and air is fitteſt for breathing when pure in high mountains, where thoſe ſalts are the leaſt to be found; nor is there any nitrous ſalt, as yet known, to be found in our blood. As for the upper part of the ſurface of the cake of blood appearing of a bright florid colour, that ariſes from a relaxation or looſer diſpoſition of the ſpherical globules there, while the bottom part appears black, becauſe the globules are there more compreſſed and condenſed by the other incumbent parts.

§. 309. If it be aſked, why tortoiſes, frogs, lizards, ſnails, ear-wigs and other inſects live long without air; we anſwer, that in them the lungs are given not ſo much for the preparation of the blood, which they receive but in a very ſmall quantity, as for the uſe of ſwimming in the water: and from hence it is that their lungs are immediately joined with the vena cava and great artery. But inſects, we know, draw the air in, and exhale it again through their ſkin. If it be aſked, why all animals periſh in air that is confined or not renewed, although the animal be ſmall, ſuch as little birds; we anſwer, becauſe the air, which has once entered the lungs, and been fouled by watry vapours, is rendered leſs elaſtic, and unfit for reſpiration by alcaline vapours. Hence it is, that the animal ſurvives longer in air that is more compreſſed, than that of the atmoſphere: for in that caſe, there is a greater proportion of the elaſtic element, which takes up a longer time to corrupt it. But even, in other caſes, confined air is rendered deſtructive only by ſtagnation, and filling it with vapours. But the reaſon, why animals ſwell in an exhauſted veſſel, is, from the extrication and expanſion of the unelaſtic air lodged in the blood and other juices.

§. 310. There is a certain conſent or proportion between the pulſe and the reſpiration; that according to the common courſe of nature, there are three or four pulſes counted to one reſpiration. But if more blood is ſent to the heart, in a given time, the numbers, both of the pulſe and reſpiration, are increaſed. This is the reaſon of the panting or ſhort breathing in a perſon that exerciſes his body with any conſiderable motion; whereby the venal blood is returned faſter to the heart (§. 142.). But if the blood meets with a greater reſiſtance in the lungs, ſo that it cannot paſs freely from the right into the left ventricle of the heart, then the reſpiration is increaſed both in the number and magnitude to forward its courſe; and this is the cauſe of ſighing and yawning. If it be aſked, why an animal that is dying may be recovered again to life, by inflating air into the lungs; we anſwer, that the proximate cauſe of death (§. 257.) is too great a reſiſtance oppoſed to the courſe of the blood through the lungs, whereby it cannot paſs to the aorta; but, by inflating the lungs, that reſiſtance is removed, and the way opened for the blood to paſs on, (§. 286.).

§. 311. The mucus, which lines the ſenſible membranes of the air-veſſels in the lungs, may become troubleſome, both by its quantity and acrimony; it has been even known to cauſe ſuffocation in a dropſy of the lungs. Therefore its quantity, adheſion or acrimony excites a cough; namely, an irritation of the reſpirative ſyſtem, by alternate large inſpirations, ſucceeded by large and quick expirations, together with ſudden ſhocks of the abdominal muſcles, by which the mucus, and ſometimes calculous matters are expelled from the lungs.

§. 312. Laughter differs from coughing in its cauſe, which reſides commonly in the mind, or, at leaſt, conſiſts in a certain titillation of ſome of the cutaneous nerves; and, moreover, becauſe it is made up of imperfect quick expirations through the contracted glottis, after one large or deep inſpiration; nor is the air perfectly evacuated from the lungs in laughter, which, in a moderate degree, conduces to health, becauſe to one full inſpiration are joined many ſhaking expirations, agitating the blood.

But much of it is in danger of ſtagnating the blood, becauſe the expiration is not full or entire, whereby the blood is admitted into the pulmonary artery without being ſuffered to paſs through it. Weeping has ſhort reſpirations like thoſe of laughter, but finiſhes with a deep expiration that is immediately joined by a large inſpiration; whence it has nearly the ſame good and bad effects; and, when moderate, it conduces to relieve the anguiſh ariſing from grief. Sneezing conſiſts of one large or deep inſpiration, which is followed immediately with a powerful and ſudden expiration.

§. 313. The additional or ſecondary uſes of reſpiration are many. [It exhales, as an emunctory, parts redundant, or even noxious from the blood, which, in confined air, ſuffocates.] It is by this force, that the abdomen, with all its viſcera, are continually compreſſed; by virtue of this, the ſtomach, inteſtines, gall-bladder, receptacle of the chyle, bladder of urine, inteſtinum rectum, and the womb itſelf, diſcharge their contents; by this action the aliments are principally ground or diſſolved, and the blood is urged thro' the ſluggiſh veſſels of the liver, ſpleen and meſentery. Moreover, inſpiration ſerves to convey odours with the air to the organs of ſmelling. By this, the air is mixed with the aliments, which it conduces very much to break and diſſolve towards a perfect digeſtion. But even ſucking, ſo neceſſary and natural to the new-born infant, is made by the uſe of reſpiration, and forming

ing an ample ſpace in the mouth, in which the air is rarefied, ſo that, by the greater preſſure of the outward air, the milk is drove into that part where it is leſs reſiſted. Laſtly, the voice itſelf is owing to the air which we breathe; therefore it may be not inconvenient for us, in this place, to deſcribe it more particularly.

LEC-

LECTURE XI.

Of the voice and ſpeech.

§. 312. THE principal organ of the voice is the *larynx*; for that being injured, the air paſſes through the wind-pipe without yielding any ſound. By the larynx, we underſtand an aſſemblage of cartilages, joined into a hollow machine or pipe, which receives the air from the fauces, and tranſmits it into the wind-pipe, having its parts connected together by ligaments and muſcular fibres. Among theſe cartilages of the larger kind, thoſe, called the anular and ſcutiform, are, in adults, frequently changed into bone. The anterior and larger part of this larynx, which lies almoſt immediately next to the ſkin, is compoſed of two cartilages, one called *thyreoides*, the other *cricoides*; to which laſt the lateral parts of the larynx are ſo joined, that the portions are always ſo much larger, as they are higher ſeated. The back part of the larynx is firſt made up by the ſaid anular cartilage, after connected by the arytænoide muſcles. The epiglottis is looſely connected above the larynx with the thyreoide cartilage, in ſuch a manner, that it may be able to riſe up and ſhut down. The blood veſſels of this part are from the upper thyreoids; and the nerves, below, are numerous from the recurrents; as above alſo there are nerves coming from the eighth pair varioűſly inoſculating. The former of theſe nerves is remarkably famous for its ariſing in the thorax, and being afterwards inflected round the aorta and right ſubclavian; and for the origin, which it gives to ſome of the nerves of the heart, as well as for the experiment, by which a ligature upon the recurrent is found to render the voice inſonorous.

§. 313. All theſe cartilages are connected together by various muſcles and ligaments, with a certain degree of firmneſs to the adjacent parts; and yet ſo, that the whole is eaſily moveable together, as are alſo its ſeveral parts upon each other. Particularly the *ſcutiform* cartilage, or the thyroidea anterior, compoſed of two plates, which are almoſt quadrangular, are inclined to each other in an obtuſe angle, which is foremoſt. Upon theſe cartilaginous plates, are ſometimes found two apertures, one on each ſide for the blood veſſels of the larynx; but are not very often to be obſerved. The upper proceſſes of this cartilage, terminating without any protuberance, are inclined upward and backward to their connection with the horns of the os hyoides by ſtrong ligaments. The lower parts of theſe cartilages are ſhorter, and adapted almoſt with a flat ſurface to thoſe of the cricoide cartilage, to which they are connected with a very firm articulation, by a ſtrong and ſhort cellular ſubſtance, uniting them on each ſide. The middle parts before, being perforated with ſtrong ligaments, are connected by the inſertion of them to the middle of the anular cartilage; and likewiſe by other ligaments above, deſcending from the horn of the ſcutiform cartilage into the upper part of the anular cartilage.

§. 314. The cricoide cartilage is before thick, and ſtrong increaſed backward; 'tis in form of a ring unequally truncated or cut through, and in its middle part is divided into two cavities by a protuberant line. This is firmer than the reſt of the cartilages, and, in a manner, the foundation of them; from this there are longitudinal muſcular fibres and ligaments, which deſcend into the wind-pipe (§. 266.). The pharynx likewiſe is connected to the ſurface of theſe cartilages by many muſcular plates, and receives the larynx as it were into its bag.

§. 315. The two arytænoide cartilages are of a very complex figure, ſpontaneouſly dividing into two parts; of which the lower is larger, and is connected by a moveable juncture with the protuberant cricoide cartilage, by a baſis moderately hollow. They aſcend upwards, of a triangular figure, with the poſterior angle hollow, the anterior convex, divided by three furrows or ſulci, and extenuated upwards, 'till they are, at laſt, finiſhed or terminated by a pretty thick, oval, cartilaginous head fixed on them. The lower part of theſe cartilages are connected by numerous muſcular fibres, partly tranſverſe and partly oblique, of which the different directions are viſible enough, but the ſeparation of them impracticable. Theſe are called arytænoide muſcles. In the upper part the arytænoide cartilage departs from its companion or fellow cartilage, leaving a rima or cleft perpendicularly betwixt them, which has been (not very properly) by ſome called the glottis.

§. 316. The arytænoide cartilages are connected with the thyreoideals, by tranſverſe ligaments ſufficiently ſtrong and elaſtic, but covered with the common mucous membrane of the larynx, which ligaments are inſerted into the flat angle of the thyreoide cartilage (§. 313.) Theſe ligaments may be drawn out or ſtretched from each other by removing the contact of their arytænoide cartilages, and may be again conjoined together by placing the cartilages one to another; and this is the true glottis, which is continuous with the ſaid rima (§. 315.), but at a right angle.

§. 317. From the ſame angle of the thyroide cartilage, under a notch, from a firm ligament is extended backwards a hollow, and ſomewhat oval cartilage, in its fore-part convex, behind concave, and raiſed up in ſuch a manner, by its elaſticity, as to project conſiderably behind the tongue; but is ſo flexible or inclinable downward, whenever the root of the tongue is preſſed backward, that, by its tranſverſe poſition, it ſhuts up all paſſage into the larynx, and defends it in ſuch a manner, that whatever is contained betwixt this part, called the epiglottis, and the arytænoide cartilages, paſſes over downward into the pharynx. The epiglottis is conjoined to the tongue by pale membranous fibres, and to the os hyoiodes it is connected by many membranous expanſions. But as for muſcular fibres from the thyreo-arytænoidal muſcles and from the ary-arytænoidal muſcles, it has either none at all, or elſe ſuch as are too minute to have any effect upon its elaſticity.

§. 318. By the ſides of the ligaments of the glottis (§. 316.), there are two other upper and ſofter ligaments, which go out parallel from the arytænoide cartilage to the ſcutiform one, which ligaments are ſomewhat leſs tendinous and leſs elaſtic. Betwixt theſe two ligaments, on each ſide (§. 318, 316.) a peculiar cavity or ventricle deſcends, having the figure of a compreſſed parabolic ſinus extended downward betwixt the double membrane of the larynx, opening conſtantly with an elliptical mouth by the ſide of the glottis in the larynx.

§. 319. Laſtly, all the internal cavity of the larynx is lined with the ſame ſoft ſenſible or irritable and mucous membrane, as we before deſcribed in the wind-pipe (§. 263.). But this membrane is watered by a great number of ſmall glands here ſituated. The uppermoſt are ſmall ſimple glands, aſſembled together in a heap (§. 201.) ſeated on the anterior and convex part of the epiglottis, upon the hollow ſurface of which they ſend out various openings, ſmall ſinuſſes, and productions; and others are, in like manner, continued there in ſmall hard acini or bunches. Moreover, upon the hollow anterior ſurface and back of the arytænoide cartilages (§. 315.), there are ſmall glandules placed on each ſide of a looſe conglomerate fabric, compoſed of little round acini or heaps, almoſt of a triangular ſhape, and are, doubtleſs, muciferous, having ſome of their looſer parts extended on each ſide as low as the anular cartilage. In the cavity of the ventricles, there are many ſmall mucous glandules; and laſtly, all the internal ſurface of the larynx is full of large mucous pores All theſe glandules ſeparate a thin watry mucus, which yet has a conſiderable degree of viſcidity.

§. 320 Perhaps the thyroeide glandule has a like uſe. It is of the conglomerate kind, but ſoft and lobular, with many coverings conſiderably large or broad in its extent, but of a more tender ſubſtance than the ſalival glands, ſeated upon the thyroeide cartilage, and in part upon the cricoide cartilage and wind-pipe, along their fore part, ſo as to incompaſs the lateral horns and ſides of the thyroeides; but aſcending upwards by a very thin proceſs before, in its middle part, as far as the os hyoides. This gland is full of a ſerous, yellowiſh, and ſomewhat viſcid humour; but whether it emits the ſame into the wind-pipe or into the gula, is not yet determined; at leaſt, there are no ducts certainly known to open into either of them. Whether or no the juices are altogether retained in this gland, and afterwards poured into the veins, in a manner reſembling the fabric of the thymus, or whether it is of the conglobate or lymphatic kind, is uncertain. Yet, that the uſe of this gland is very conſiderable, may appear from the largeneſs of the arteries, which it receives from the carotids and lower ſubclavians. The veins thereof return their blood into the jugulars and ſubclavians. It has a pe-

peculiar muſcle, not conſtantly to be found, ariſing from the edge of the os hyoides, and ſometimes from the lower margin to the left of the thyroeide cartilage, which deſcends without a fellow, ſpreading its tendinous fibres over the gland. Upon which alſo the ſternohyoidei and ſternothyoeridei muſcles are likewiſe ſpread or incumbent.

§. 321. The whole larynx, together with the conjoined os hyoides, is capable of being raiſed conſiderably, at leaſt half an inch above its mean altitude; which elevation is performed by the biventer muſcles, together with the geniohyoidei, genioglоſſi, ſtylogloſſi, ſtylohyoidei, ſtylopharyngei, thyreopalatini, hyothyreoidei; all or ſome of which conſpire together in that action. In this elevation the glottis is preſſed together or made narrower, and the ligaments beforementioned (§. 316.) approach nearer together. But thus, by the aſſiſtance of the action of the arytænoide muſcles, together with the oblique and tranſverſe ones, the glottis may be accurately cloſed, ſo as to reſiſt with an incredible force the preſſure of the whole atmoſphere.

§. 322. The ſame larynx may be, in like manner, depreſſed to about half an inch beneath its ordinary ſituation by the ſternohyoidei, ſternothyreoidei, and caracohyoidei, as they are called; and, when theſe are in action, alſo by the joint force of the anterior and poſterior cricothyreoidei. In this motion the arytænoide cartilages depart from each other, and render the glottis wider, which is alſo drawn open laterally by the muſcles inſerted into the ſides of the arytænoide cartilages, together with the cricoarytænoidei poſtici and laterales. The thyreo-arytænoidei, incumbent on theſe parts, may compreſs the ventricles of the larynx (§. 318.).

§. 323. Hitherto we have given the anatomy of theſe parts, It remains, therefore, that we demonſtrate what action the air produces, when it is driven by the foreſaid powers (§. 295.) from the lungs in expiration through the wind-pipe into the larynx, and from them urged out through the glottis into the mouth variouſly configured. The conſequences or effects of this, are voice, ſpeech and ſinging. And firſt, the voice alone is formed, when the air is expelled with ſo great a velocity thro' the contracted glottis, that it ſplits or makes a colliſion upon the glottid ligaments, ſo as to put the larynx into a tremor, which tremor is returned and continued or increaſed by the elaſticity of theſe parts. Sound, therefore, ariſes from the conjunct trembling of the ligaments (§. 316.), together with the cartilages of the larynx at one and the ſame time, which we then call the voice, and is of a peculiar kind or modulation in every ſingle claſs of animals, depending entirely upon the difference of the larynx and glottis. But when a trembling is not excited, the expired air cauſes a whiſper.

§. 324. The ſtrength of the voice is proportionable to the quantity of air blown through the glottis; and, therefore, a large pair of lungs, eaſily dilatable with an ample larynx and wind-pipe, joined with a powerful expiration, all conduce to this effect. But acute and grave tones of the voice, we obſerve to ariſe from various cauſes, The former proceeds from a tenſion and narrowneſs of the glottis, and the latter from a relaxation and expanſion of it. For thus, in the former, a greater number of air-waves are ſplit in the ſame time upon the ligaments of the glottis, whence the tremors, excited at the ſame time, are more numerous; but when the glottis is dilated, the contrary of all this follows. Therefore to produce an acute and ſhril voice, the larynx is drawn up more powerfully, as the voice is required to be ſharper, inſomuch that an inclination of the head forward is called in to aſſiſt, by which the powers of the muſcles, elevating the larynx, are rendered more full and effectual. The truth of this is confirmed' by experience, by applying the fingers to the larynx when it forms an acute ſound; for then to raiſe the voice an octave, you will eaſily perceive it to aſcend near half an inch: alſo the ſame is evident from comparative anatomy, which demonſtrates the narroweſt glottis and the cloſeſt approximation of cartilages in canorous birds; but an ample or broad glottis in hoarſe animals and ſuch as bellow or bleet; an inſtance of this we have in whiſtling, where the voice manifeſtly becomes more acute by a contraction or narrowneſs at the mouth: and likewiſe alſo in muſical inſtruments, in which a narrowneſs of the mouth or opening that expels the air, with a celerity of the wind blown out, are the cauſes of an acute of ſhrill tone.

§. 325. Gravity of the voice, on the contrary, follows from a depreſſion of the larynx by the cauſes (§. 323.) already deſcribed; to which add a broad glottis and a very ample larynx. This is evident to the touch of the finger applied to the larynx, when a perſon ſings, by which the deſcent of it is manifeſtly perceived to be about half an inch for every octave; hence the voice of males is more grave; and hence the loweſt degrees of the voice degenerate into a muteneſs or whiſpering.

§. 326. Singing is when the voice, moduluated through various degrees of acuteneſs and gravity, is expelled thro' the larynx, while it is trembling and ſuſpended betwixt two contrary powers; and herein lies the principal difference betwixt the chanting of ſimple notes, and the expreſſion of words. Hence it appears to be a laborious action, by reaſon of the continual contractions of the muſcles, which keep the larynx at an equilibrium; and hence it is, that ſinging makes a perſon hot, becauſe in acute tones the narrower glottis much retards the expiration, while, at the ſame time, a great deal of air is required to give ſtrength to the voice (§. 324.); towards which again deep inſpirations are neceſſary. Hence likewiſe the wind-pipe is rendered very dry, from the quicker paſſage or current of air, to prevent which a great deal of mucus is required; and, therefore, it is, that there are ſuch numbers of mucous receptacles in the larynx, amongſt which, I am firmly of opinion, the ventricles before deſcribed (§. 318.) ought to be numbered.

§. 327. Speech is performed by the larynx at reſt, or held in the ſame place, in tones of voice differing but little in acuteneſs and gravity; but then the voice is variouſly changed or modulated by the organs of the mouth. Canorous ſpeech has a variation in the tone or cadence of the voice, together with a modulation of it by the organs of the mouth at the ſame time.

§. 328. All ſpeech is reducible to the pronunciation of letters, which differ in various nations; but moſt of them are alike all the world over. Of theſe, ſome are called vowels, which are made only by an expreſſion of the voice through the mouth, without any application of the tongue to certain parts of the mouth. But conſonants are formed by a colliſion of the tongue againſt certain parts of the mouth, lips and teeth. But to be more particular in theſe matters is beſides our purpoſe, which will not permit us to expatiate upon the beautiful art of pronunciation. That art, as an extraordinary inſtance of mechanical knowledge, has ſo accurately determined all the corporeal cauſes concurring to each letter, that, by inſpection only, with the aſſiſtance of touch, letters pronounced are underſtood without hearing them, and the attentive perſon is thereby taught to imitate the ſame ſpeech by a like uſe of the organs.

§. 329. Whether or no all the difference of tone in the voice depends entirely upon the length of the ligaments of the glottis, increaſed by the ſcutiform cartilage drawn forward, and the arytænoide cartilage drawn backward, in ſuch a manner, that the ſharpeſt are thoſe made by the ligaments in the greateſt tenſion, and, therefore, with a quicker vibration? this had been advanced by the experiments of ſome gentlemen of note, and ſince repeated by other anatomiſts, [who judge, that the tenſe chords or ligaments of the glottis do, from the air perflated by the wind-pipe, produce the voice and its ſeveral tones in animals; ſo that greater tenſity and cloſure of the ligaments yields a more acute voice, as a laxity of them occaſions a more grave tone of the voice. That thoſe ligaments, drawn cloſe, ſuppreſs the voice; or being half way ſhut, and the reſt open, they give a tone that is one octave higher; as a third part of them, thus ſhut, yeilds a fifth higher, &c.] I ſhall not take upon me to determine in a matter of ſuch importance, that has not yet fallen under my examination experimentally; there are conſiderable doubts or objections to be made againſt this ſyſtem, taken from the cartilaginous and bony glottis, which is thus immoveable, and in no ways extenſible in birds; alſo from the voice becoming infallibly more acute in whiſtling, merely by a contraction of the lips only; alſo from the inſtance of women, who having a ſhorter larynx and glottis than men, nevertheleſs utter a more ſhrill voice; likewiſe from the experiment, by which it appears, that the tone becomes more acute by approximating the ligaments of the glottis nearer together; again, from the doubtfulneſs of the credit upon which thoſe new experiments are publiſhed; from the want of a machine of any perfection to draw the ſcutiform cartilage forward; and laſtly, from a ſtrong and evident ſuſpicion, that the author of the experiment imagined the ſcutiform cartilage to be drawn forward, when it was, in truth, only elevated. Therefore this invention merits further enquiry; and as the author's laudable endeavours are not to be here diſcouraged by a refutation, ſo neither are they to be haſtily embraced with too much credulity.

LECTURE XII.

Of the brain.

§. 330. THE remaining actions of the human body, we ſhall conſider according to the order by which they receive the blood from the arteries. The coronary arteries, we ſpoke of before, when we gave the hiſtory of the heart; but next to thoſe, the carotid arteries paſs out from the aorta.

§. 331. The aorta, which comes out from the anterior part of the heart (§. 128.), in order to bend itſelf towards the vertebræ of the thorax, forms there a conſiderable arch, by which it is bent backward, and towards the left, in angle that is round but not very large. From the convexity of this arch, three conſiderable branches ariſe, of which the firſt aſcends towards the right ſide, and is immediately ſubdivided into two large arteries. The lowermoſt goes on in the direction of its trunk, under the denomination of the ſubclavian. The other aſcends according to the courſe of the wind-pipe to the head, and is called the *right carotid.* The *left* carotid ſprings next, a little inclined from the ſame arch further to the left ſide; and the third, which is ſtill more inclined to that ſide, is called the left ſubclavian, which is ſomething leſs than the right. About the origination of theſe arteries, the next continuous margin of the aorta is a little thicker and more protuberant. [But variations from this courſe are obſerved rarely.]

§. 332. The carotid artery commonly aſcends as high as the thyreoide cartilage, without ſending off any branches, wrapped up together with the jugular vein and nerve of the eighth pair, in a thick, denſe, cellular ſubſtance. There, at the ſaid cartilage, it divides into two trunks, one anterior, called the *external* carotid, which is rather larger and more in the direction of its trunk; and this conſtantly ſends off a branch called *thyreoidea*, ſuperior to the gland of the ſame name, to the gula, to the poſterior and anterior muſcles of the larynx. This branch ſometimes ariſes alſo below the diviſion of the carotid. The ſame external carotid ſends off from its inner ſide, the inflected arteria *lingualis*, and then the *labialis*, which, having given branches to the tonſils, moveable palate and uvula, aſcends in a ſerpentine courſe over the face to the termination at the noſe, and communicates by inoſculations with the opthalmic artery, and with its fellow artery on the other ſide. From the poſterior face of the carotid, the next artery which ariſes, is the pharyngea aſcendens, which, beſides the pharyngea and branches to the muſcles of the moveable palate, ſends likewiſe a conſiderable branch in common with the nerve of the eighth pair through the foramen of the jugular vein to the dura mater, very near to the great foramen of the occiput, and by the os petroſum; afterwards this artery divides itſelf at the cuneiform proceſs of the multiform bone.

§. 333. Again, from the outer edge of the external carotid, ſprings the *occipital* artery, which ſends branches not only to the muſcles, which give it a name, but likewiſe ſends a branch through a peculiar foramen of the dura mater in the angle, which the os petroſum forms by departing from the mamillary proceſs, which artery is ſpread through the ſeat of the cerebellum; another branch paſſes over the atlas to the dura mater under or into the ſkull; and a third ſometimes goes through the foſſa jugularis to the dura mater. The next artery, which is the *auricularis*, goes to the back part of the ear, to the temple, and to the membrane of the tympanum.

§. 334. What remains of the external carotid artery, aſcends through the parotid gland, to which, having given ſome branches as well as to the face and eye-lids, it ſends out the *temporalis*, which is a conſiderable ſuperficial artery upon the integuments of the bones of the temples and forehead. The trunk of the carotid, being inclined, conceals itſelf behind the lower jaw, under the denomination of *maxillaris interna*.

§. 335. In that place, it directly ſends off a large trunk, which paſſes to the dura mater through a peculiar opening of the broad and pteryoide wings, ſeated at the middle foſſa of the brain; from whence they are largely ſpread through the temples and forehead within the dura mater, as far as the falciform ſinus. Sometimes

times this artery is double, and often gives out a branch, that is conſpicuous to the lachrymal gland of the eye. In the ſame place likewiſe, the maxillary artery enters in, under the root of the wings through the ſphenomaxillary fiſſure; whence aſcending, it paſſes by a threefold trunk as far as the upper part of the nares; where it is ſpent, after having given off the branches called maxillaris inferior, and the ſuperior to the teeth, with the infra orbitalis, to part of the face and eye-lids, and the palatina to the bone of the palate, with ſmall branches to the dura mater, and others through the ſmaller pores of the great wings, with ſuch as accompany the third and ſecond branch of the fifth pair of nerves; and laſtly, together with the dura mater filling up the lower orbital fiſſure.

§. 336. But the other poſterior trunk, commonly called the *internal carotid* (§.332.) aſcends without a branch. This artery, having firſt made a conſiderable ſerpentine flexure, enters through a peculiar foramen in the os petroſum, where it is ſurrounded with a capſule from the dura mater, like that which comes out through all the openings of the ſkull; from thence it aſcends upwards and inclined forwards, 'till, having penetrated into the cavity of the ſkull, it riſes up inflected and in a curvature, according to the direction of the ſella equina, in the middle of which, there is a cavernus or hollow ſinus, retarding the blood; from thence, having given ſmall branches to the fifth pair of nerves, it ſends others to the infundibilum and dura mater, with one larger to the eye, part whereof returns again through a peculiar hole into the dura mater, which lies upon the middle of the orbit.

§. 337. But the trunk of this internal carotid, paſſing over the anterior part of the ſella equina, is incurvated backward, and being received by the arachnoide membrane, giving branches to the pons and crura of the brain, with a circle to the choroide plexus, and one that accompanies the optic nerve, it then divides into an anterior and poſterior branch. The former, being conjoined with its fellow artery of the other ſide by a ſhort inoſculating branch, which ſometimes ſprings from the trunk itſelf, is then incurvated backward and upward, according to the direction of the os calloſum, and ſpreads itſelf about the middle part of the brain. The latter or poſterior diviſion of the carotid, being conjoined by a ſmall inoſculating branch with the vertebral artery, afterwards aſcends a long way upon the ſide of the brain through the Sylvian foſſa. All the branches of the carotid, contained within the ſkull, are made up of more thin, ſolid and brittle membranes than the other arteries of the body.

§. 338. But the *vertebral artery*, commonly ariſing from the ſubclavian of the ſame ſide, though the left has been ſometimes ſeen to ſpring from the trunk of the aorta, paſſes on without giving branches through a place of ſecurity, 'till it enters a foramen in the tranſverſe proceſs of the ſixth vertebræ of the neck, after which it continues with alternate flexures to aſcend through the oblique proceſſes of the other vertebræ of the neck; from whence, at each interval, it ſends off ſmaller branches to the muſcles of the neck, and communicates with the lower thyreoideal; other branches again ſomewhat larger go from it backward, together with each of the nerves, to the pia mater of the ſpinal medulla; but before, the branches are larger though leſs numerous, to the ſame ſpinal medulla, and communicate by an anaſtomoſis, with its ſpinal artery anteriorly. Laſtly, growing leſs about the ſecond vertebra, and being inflected with a large curvature round the tranſverſe proceſs of the firſt vertebra, it there ſends off conſiderable branches to two of the muſcles of the neck; alſo ſmall branches it ſends off in its courſe through the great foramen of the occiput or ſkull to the dura mater, which lines it, and the adjacent cavities that contain the cerebellum; after which, it goes on through the ſaid foramen into the cavity of the ſkull. There aſcending, according to the courſe of the medulla oblongata, the right trunk, by degrees, approaches nearer to the left, and is conjoined together with it (in an extraordinary manner, hardly to be found in other parts) into an artery called the *baſilaris*, which is ſuſpended in the pia mater all along under the pons Varolei. From the vertebral arteries, before they are conjoined together, paſs out branches, which go to the lower ſurface of the cerebellum, and are deeply inſerted under the fourth ventricle to the inner ſubſtance of the cerebellum. Theſe are the branches ſent off by the ſpinal arteries. But there are ſome inſtances where they ariſe conjunctly from a ſingle trunk; and then the next artery, which it ſends off, is the baſilaris: but beſides branches to the medulla oblongata and crura of the brain, it gives firſt the lower arteries of the cerebellum, then the upper and ſuperficial ones, with ſmall branches, to the fore part of the fourth ventricle. Amongſt the foreſaid branches alſo ariſes an artery, which accompanies the auditory nerve. Finally, the baſilaris, at the fore-part of the pons, divides into two branches, each of which communicates with the poſterior branch of the carotid, and goes partly to the poſterior lobe of the brain, partly to the ſurface of the cerebellum, and in part to the nates, teſtes and upper portion of the charoidal plexus; and in part likewiſe enters the anterior ventricles of the brain, and goes along with the lower portion of the choroides to the corpora ſtriata, fornix, &c.

§. 339. From the foregoing hiſtory of the arteries belonging to the brain, it appears, that a very great quantity of blood is in every pulſation ſent to this organ, inſomuch that it makes above a ſixth part of the whole blood, that goes throughout the body, and derived from trunks that are very near the heart, ſpringing from the convexity of the aorta. From hence it is probable, that ſuch parts of the blood go to the head, as are moſt retentive of motion. Is not this evident from the effects of mercurials exerting themſelves almoſt in the head only; from the ſudden force and action of inebriating ſpirits upon the head; from the ſhort ſtupor which camphor excites; from the heat, redneſs and ſweat, which happen oftner in the face than other parts of the body; to which add the more eaſy eruption of volatile and contagious puſtules in the face? The well-guarded paſſage of theſe great and important veſſels, in their aſcent to the head, defends them from any great injury. The frequent inoſculations of one trunk, with the other going to the head, as well as the frequent communications of their branches among themſelves, leſſen any danger that might enſue from obſtruction. The conſiderable flexures of the vertrebral and carotid artery ſerve to moderate the impulſe of the blood coming to the brain, ſince a great part of the velocity, which it receives from the heart, is thus ſpent in changing the figure of the inflections. To which add, that ſome authors do not improperly obſerve the arteries here grow larger or ſomewhat wider.

§. 340. The hiſtory of the brain deſervedly begins from its integuments. Such a tender part ſo neceſſary to life, we obſerve providently ſurrounded on all ſides, firſt by a ſphere of bones, conſiſting of many diſtinct portions; by which means it is rendered extenſible, at the ſame time that it is effectually guarded againſt external preſſure. To the internal ſurface of this bony ſphere, on all ſides, grows a very ſtrong membrane, compoſed of two plates ſufficiently diſtinct, which are firmly attached by an infinite number of ſmall veſſels, as by ſo many foot-ſtalks to the whole ſurface of the ſaid bones; ſo as to be no where eaſily ſeparable in a healthy perſon; theſe, being very thin and ſmooth, adhere leſs firmly to the bones, but more ſtrongly to the ſutures, ſo called from their figure, which join the bones of the ſkull one to another. In younger ſubjects, the adheſion of the dura mater to the ſkull is ſuch, that the ſeparation of it pulls off the fibres of the bones to which it is connected. In adults, many of the veſſels, which it inſerts, being effaced, renders it more eaſily ſeparable; yet it is not without ſome force, even in thoſe, that the dura mater can be ſeparated from the ſkull. From the rupture of theſe veſſels, which enter the bones of the ſkull, appear thoſe bloody drops, which are obſervable after removing the cranium. Hence appears the vanity of all that has been advanced concerning the motion of the dura mater. But for the motion, which is remarked by the writers of obſervations upon wounds in this part; that, being præternatural, was the conſequence of the beating of the arteries, in a part where the reſiſtance of the bone was now removed, while the reſt of the dura mater, next to the ſkull, ſuſtained the force of the heart without motion. [Alſo that part, which is properly the dura mater, has neither nerves, nor ſenſation or irritability.]

§. 341. The *outer plate* of the dura mater, which adheres to the bones of the ſkull, is to them inſtead of a perioſteum, and ſupplied or furniſhed with ſmall nerves and blood-veſſels coming through all the ſmall holes of the ſkull;

from whence, and from its coheſion with the perioſtia of the head, ſpine and whole body, it has from the Arabians received the name mater. The *internal plate* of the dura mater is, in moſt parts, continuous with the former, but, in ſome ſubjects, it recedes a little from it, as in the great ſphenoidal wings, and at the ſides of the ſella equina, where a good deal of blood is poured betwixt them; and they likewiſe recede thus upon the ſella equina itſelf: the ſame plate, having left the outermoſt, adhering firmly to the bones of the ſkull, deſcends doubled together to form the falx, which ariſes firſt from behind the proceſſus criſtæ-galli of the multiform bone, afterwards from the criſta itſelf, and from the whole junctures of the bones of the forehead and the parietals; and laſtly, it ariſes from the middle of the back part of the occipital bone, and growing broader backwards, it divides the hemiſpheres of the brain, betwixt which it is placed; from whence departing, it is extended to the corpus calloſum. That there are ſhining fibres in this part, diſperſed towards the longitudinal ſinus from the conjunction of the tentorium, in the ſhape of branches and palm twigs, is certain; but it does not, therefore follow, that they have any muſcular motion; and betwixt theſe fibres frequently there is no membrane, only natural foramina are interpoſed. The falx is both joined to, and continued from the middle tentorium, which is extended laterally. In the ſame manner, with ſome difference of ſituation, the ſaid falx ſends out a ſhort plate downward, which divides the cerebellum, together with the ſtrong tentoria or lateral productions, which, ariſing from the cruciform protuberance of the occiput, are interpoſed tranſverſely betwixt the brain and cerebellum, extended as far as the limits of the os petroſum, and connected to the anterior clinoide proceſſes, leaving an oval aperture for the medulla oblongata to deſcend freely. Theſe productions of the dura mater ſerve to prevent the parts of the brain from preſſing one another, in all ſituations and poſtures of the body; and they likewiſe hinder one part of the brain from bruiſing the other, by any ſhock or concuſſion. Hence it is, that in the more active quadrupedes, where a concuſſion is more likely to happen, the brain and cerebellum are divided by a bony partition.

§. 342. In the external ſurface of the pia mater, not far from the ſinus of the falx, are placed ſmall glandules, of which ſome are more hard and red than others, ſeated in the reticular texture of the hard membrane, looking towards the ſinus, to whoſe cavity they are oppoſed, in ſuch a manner, that ſome of them are contiguous to the hollow of the ſinus; others are ſo placed at the inſertion of the larger veins into the pia mater, that, together with the former, they make up a continued range or ſeries; others of them again are ſoft, oval, and diſpoſed in heaps or aſſemblages. But the vapour, which exhales from the ſurface of the pia mater, is not ſeparated by theſe glands, for it is every where exhaled, even into the ventricles, where there are none of thoſe glandules; and it plentifully tranſpires every where from the mouths of the leaſt arteries, as we ſee, by experience, when water or fiſh-glue are injected, which ſweat out through every point in the ſurface of the dura mater.

§. 343. The next covering of the brain, which is more cloſe to it, exactly reſembling its figure, and adapting it to that of the hollow ſkull, has been, by ſome, denominated, from its tenuity, *arachnoides*, i. e. like a ſpider's web. This very thin or tender membrane, being pellucid like water, every way ſurrounds the brain, whoſe inequalities it climbs over, and, according to its little ſtrength, ties together with the larger veſſels, over which it is ſpread, in ſuch a manner, that the ſaid veſſels ſeem to run betwixt the pia mater and arachnoides; which laſt is, therefore, no part or lamella of the pia mater, from which it differs by ſituation, and that, in a moſt remarkable manner, more eſpecially on the ſpinal medulla.

§. 344. The third or innermoſt covering of the brain, which is ſoft and cellular, is properly the *pia mater*. This immediately inveſts or ſurrounds the whole ſurface of the brain on all ſides, is extremely vaſcular, tender, and ſomewhat of a cellular ſubſtance. The cells of which again contain an infinite number of moſt minute veſſels, which are, by this cellular fabric, exhibited like little roots or bunches of cotton to the brain. This deſcends betwixt every furrow and fiſſure of the brain and cerebellum, and even inſinuates itſelf into the ſpinal medulla. This, being received into the cavities of the brain, changes its fabric, ſo as to become ſoft and almoſt of a medullary conſiſtence, more eſpecially when the ſubject, that comes under the examination of the knife, has lain dead ſome conſiderable time, yet then it is able enough to demonſtrate the veſſels themſelves in its fabric.

§. 345. The *veins* of the brain are not diſpoſed in the ſame manner with thoſe in other parts of the body. For neither have they any valves, nor do they run together in company with the arteries, nor have their trunks the ſtructure which is commonly obſerved in the other veins. The veins, therefore, which come out of the innermoſt cavities of the brain, thoſe which are ſpread upon the ſtriated bodies, the veins of the choroide plexus, with the lucid ſeptum and the anterior ventricles, are collected together into trunks, which, at laſt, meet in one great vein or often two, which, being accompanied with many ſmall arteries of the choroide plexus, deſcends backward to the partition of the brain and cerebellum (§. 342.). In that place, it receives veins ariſing from the poſterior and lower part of the brain, and ſome of the cerebellum, from whence the blood paſſes into a ſinus, which is a kind of vein included in a reduplication of the inner plate or membrane of the brain, into which the veins, to ſhorten their length, are generally inſerted; and this ſinuous vein generally deſcends to the greater ſinus on the left ſide, though ſometimes it ends bifurcated, one branch on each ſide.

§. 346. The upper and ſuperficial veins of the brain are large, and ſpread in the windings, with which the brain on all ſides abounds. With thoſe veins, through the whole ſurface of the brain, are inſerted other veins of the dura mater; and others, which enter by peculiar orifices, into the falciform ſinus. From thence the veins, gradually collected together, paſs along moſt of them forward, ſome few of them in a ſtrait direction, and others backwards, of which thoſe forward are the largeſt, and open themſelves by ſinuſſes obliquely cut off into the long *falciform ſinus*, which is formed by the right and left plate of the internal membrane of the dura mater, which meet together below upon the upper part of the back of the falx. From thence it is of a triangular figure, convex in its upper ſide, beginning with a ſlender origin at the ſeat of the foramen cæcum, that is placed above the criſtagalli; from whence it aſcends and follows in the courſe of the falx, until that joins the tentorium; it is generally inclined to the right ſide, and takes the name of the *right tranſverſe ſinus*, which then goes by a peculiar channel in the occipital and temporal bone, tranſverſely to its incurvation at the opening of the jugular vein; in which place, being much enlarged, it receives the lower ſinus petroſus, together with the occipital ones, which are hereby diſcharged into the jugular vein. But the left tranſverſe ſinus reſembles the former, and is like that conveyed in a ſimilar courſe to the jugular vein, into which it is rather inſerted on the right ſide than continued, as it were, in a trunk. Into the ſaid longitudinal ſinus, the fourth ſinus (§. 345.) together with the occipital ſinus, uſually inſert themſelves. But there are ſome inſtances, where all theſe are diſpoſed, in a different manner, by an inſertion of the longitudinal, into the left tranſverſe ſinus; and then the right tranſverſe ſinus receives the fourth and the occipital one. At other times they are equally divided into two tranſverſe trunks; and ſometimes the middle ſinus joins the tranſverſe ones.

§. 347. There is a ſlender and rounder ſinus, which runs along the lower and thicker margin of the falx, ſomewhat of an irregular figure, receiving veins from the falx itſelf, and communicating likewiſe with the upper ſinus; it alſo receives veins from the adjacent hemiſpheres of the brain, and from the corpus calloſum. Where the tentorium joins with the fore-part of the falx, this is commonly there inſerted, into the fourth ſinus.

§. 348. The *lower veins* of the brain, which lie next to the baſis of the ſkull, are variouſly inſerted. The foremoſt of them coming from the foſſa Sylviana, collected together into ſome trunks, are inſerted into the cavernous ſinus or triangular interval, that lies at the ſide of the ſella equina, betwixt the external and internal plate of the dura mater. Other veins, from the pons itſelf, lead into the upper ſinus petroſus. Other poſterior veins, which come from the poſterior lobes of the brain, are inſerted in great numbers into the tranſverſe ſinus that is ſeated within the tentorium.

§. 349.

349. The upper veins of the cerebellum, meeting together in large trunks, partly open themſelves into the fourth ſinus, and in part into the tranſverſe ſinus. The lower veins, from the cerebellum and medulla oblongata, inſert themſelves into the upper ſinus petroſus.

§. 350. There are ſtill many ſmall ſinuſſes, beſides thoſe before-mentioned. The moſt anterior of them, which is commonly *like a circle*, is larger behind than in its fore-part, which is ſlenderer, and ſurrounds the pituitary glandule betwixt the clinoide proceſſes, communicating with the cavernous and with the lower petroſe ſinuſſes; likewiſe communicating betwixt thoſe proceſſes and the carotid of nerves, artery, and again by the way of the ſixth pair, with the upper petroſe ſinuſſes behind the fifth nerve. There are ſome inſtances, where this ſinus receives the ophthalmic vein; and ſometimes the tranſverſe, joining to the cavernous ſinus, ſupplies the place of this circular ſinus, or elſe is preſent with it at the ſame time.

§. 351. The upper *petroſe ſinus* is conveyed backwards in a cavity of the os petroſum, and takes its origin from the extremity of the anterior ſulcus of the os petroſum, where it communicates with the cavernous ſinus, and receives the inſertions of the veins of the dura mater, and ſometimes of the anterior veins of the brain itſelf, mentioned before (§. 348.); then it is inſerted into the angle of the tranſverſe ſinus, where it begins to be bent. Another vein likewiſe deſcending down through the os petroſum, is, in like manner, inſerted into the angle of the tranverſe ſinus. The *lower ſinus petroſus*, which is larger, goes round the root of the bone of this name, and communicates with its fellow behind the clinoide proceſs; alſo twice it communicates with the cavernous ſinus and with the upper ſinus, and is conjoined under the nerve of the fifth pair, being finally inſerted into the jugular foſſa or cavity. Moreover, it receives ſome veins from the vertebræ. To the ſame outlet alſo the *occipital ſinus* leads on each ſide, which being pretty large, goes round the margin of the foramen, 'till, arriving at the falx of the cerebellum (§. 341.), it is ſooner or later inſerted, together with its fellow, for the moſt part into the fourth ſinus, and with that into the left tranſverſe one, or into the longitudinal ſinus itſelf; or laſtly, by a divided extremity into each of the tranſverſe ſinuſſes. This ſinus receives the lower and poſterior veins of the dura mater, and ſome others from the vertebræ.

§. 352. The anterior occipital ſinus is irregular or multiform, partly tranſverſe and partly deſcending to the great foramen, being variouſly conjoined with the lower petroſe ſinuſſes; from whence it paſſes with the nerves of the ninth pair, and either communicates through a peculiar foramen by emiſſaries into the outer vertebral vein, or other branches paſſing out below, open into the venal circles of the ſpinal medulla. But the *cavernous ſinuſſes* of the dura mater (§. 345.), being ſurrounded with a good deal of cellular ſuſtance, receives, beſides the fore-mentioned ſinus (§. 349, 350.), large veins already deſcribed, and tranſmits them with peculiar veins, together with the firſt and ſecond nerve, and third branch of the fifth pair, with a large artery of the dura mater (§. 335.), and the internal carotid (§. 336.); alſo it ſends out other emiſſaries through a foramen, which is not conſtant in the great wing, which form inoſculations with veins placed on the outſide of the ſkull leading to the jugulars, and eſpecially with the largeſt pterygoidal plexus of veins belonging to the noſe. The great vein of the dura mater, whoſe branches are accompanied with an artery, is often double and inſerted into one of thoſe emiſſaries which we have deſcribed. In the ſame manner, the veins of the pericranium paſs through ſmall holes in the parietal bones into the longitudinal ſinus, as the occipital veins paſs through the maſtoide hole into the tranſverſe ſinus thro' the anterior channel of the occipital bone, and the external vertebral veins are inſerted into the jugular ſinus; and others of the anterior occipital veins, accompany the nerve of the ninth pair. Thus there are an infinite number of ways open to the blood, by which it may paſs from the ſinuſſes, wherein it is often collected in too great a quantity; but, by this mechaniſm, it may eſcape either on one ſide or the other, according to the different laxity and declivity of the parts. [Hence no violent ſymptoms follow upon tying either or both of the jugulars or other large veins.]

§. 353. The great quantity of blood, which goes to the brain, the greater impulſe with which it is ſent into the carotid arteries (§. 339.), and the immunity of this part from every kind of preſſure by a ſtrong bony fence, joined with the ſlower motion of the blood through the abdominal viſcera and lower extremities, alſo the perpetual exerciſe of the brain and ſenſes, do all determine a copious flux of blood to theſe parts, and are likewiſe the cauſes, why, upon every increaſe of the circulation, the head is more particularly and ſurpriſingly filled with blood. Hence it is, that a redneſs of the face, a turgeſcence and ſparkling of the eyes, with a pain and pulſation or throbing of the arteries in the head, are ſo frequently followed with a bleeding at the noſe, by violent exerciſes or motions of the body. From hence, therefore, it is evident, that, if the veins were of a thin and round ſtructure in the brain, they would be unavoidably in greater danger of breaking, whereby apoplexies (to which, in their preſent ſtate, they are often liable) would be much more frequent. To avoid this, therefore, nature has given a different figure to the veins which carry out the blood from the brain, by which they are more eaſily and largely dilatable, becauſe they make an unequal reſiſtance; their texture is likewiſe very firm, and more difficultly broken, eſpecially in the larger ſinuſſes, which perform the office of trunks; for as to the ſinuſſes of the leſſer ſort, they are either round, half cylindrical, or of an irregular figure. Beſides this, nature has guarded the ſinuſſes by croſs-beams, internally made of ſtrong membranes, and detached from the right to the left ſide within the ſinus, which, in greater diſtenſions, they draw towards a more acute angle, which is capable of a larger dilatation, ſtrengthening and guarding it from a rupture at the ſame time. She has likewiſe, in theſe veins, provided numberleſs inoſculations, by which they open mutually one into another, and openly communicate with the external veſſels of the head and with thoſe of the ſpinal medulla, by which means they are capable of freeing themſelves more eaſily, whenever they are overcharged with blood, (§. 352.).

§. 354. It is by ſome queried, whether a part of the arterial blood is not poured into the ſinuſſes of the brain? and whether they have not a pulſation excited from that blood? that they have no pulſation is paſt doubt, becauſe the dura mater every way adheres firmly to the ſkull, but much more firmly in thoſe parts, which are the ſeats of the ſinuſſes. Indeed they receive liquors injected by the arteries; but whether thoſe tranſude through the ſmall exhaling arterial veſſels, or whether they firſt make a compleat circle through the veins, as is moſt probable, we are not yet furniſhed with experiments enough to determine.

§. 355. Thus all the blood of the brain or encephalon is finally conveyed into the jugular veins, which are very dilatable, and, for that reaſon, guarded with valves to prevent a return of the venal blood from the right auricle, being, at the ſame time, ſurrounded with a good deal of cellular ſubſtance. For as to the blood, which goes to the head by the vertebral veins, it is a very inconſiderable quantity; but the ample jugulars anſwer, in ſuch a manner, to the great upper vena cava, in a direct courſe, that they afford the high way for the blood to return back to the heart.

§. 356. Whether or no there are lymphatic veſſels to be ſeen in the brain, is by ſome queſtioned? Indeed we read deſcriptions of them in the pia mater, and in the larger choroidal plexus; but, for my own part, I have never been able to ſee them, and poſſibly there are none to be ſeen, ſince there are no conglobate or lymphatic glands in the brain, which are always near at hand, wherever any of theſe veſſels are to be found. As for the various accounts, which are given of the pituitary glandule, of the infundibulum, and of the ducts, which lead from thence into the veins of the head, abſorbing and tranſmitting a water from the ventricles of the brain; they are not ſupported by anatomical experiments, which make it more probable, that the vapour, which is ſecreted into the ventricles of a healthy perſon, is, in like proportion, abſorbed again by the inhaling veins, or if any part abounds, that deſcends through the bottom of the ventricles to the baſis of the ſkull, and from thence into the looſe cavity of the ſpinal medulla. That this is the caſe, appears from palſies, which enſue on one ſide of the body after apoplexies; and from the bifide ſpines or watry tumours in the lower part of the ſpinal medulla, following in thoſe who have an hydrocephalus. But the ſaid pituitary glandule receives into itſelf a ſtrong medullary cone, which yet is inſerted ſoft and very much like the cortical ſubſtance of the brain, more eſpecially in its poſterior appendix, which is extended to the poſterior clinoide proceſſes; but it is neither of any certain or known uſe, nor like unto any glandule, with which we are acquainted.

§. 357. It now remains for us to ſpeak of the encephalon itſelf. But many are the parts included under this general denomination. By the *brain*, properly ſo called, we underſtand that upper and ſoft viſcus, which is contained in the ſkull, and which is lodged by itſelf in its fore-part, but backward 'tis incumbent over another conſiderable part, called the *cerebellum*, which lies in the poſterior and lower cavities of the occipital bone, under the membranous tentorium, which parts it from the brain, whoſe lower, middle and white portion, deſcending before the cerebellum, is, in part, called the pons, and, in part, the *medulla oblongata*.

§. 358. The *figure* of the brain reſembles that of half an egg, which is deeply divided longitudinally, but not cut through above half way. Both the upper and lower ſurfaces are full of many gyri or convolutions, which pretty deeply cut or divide the brain with round ends or angles into undulated portions. Upon the ſurface of the ſaid lobules or portions lies the *cortex*, extremely ſoft and inclined from a yellow or red to a grey or aſh colour, being the moſt tender of all parts in the human body: this inwardly is filled with the *medulla*, which is almoſt perfectly white, except that, in many places, it is perforated by red arteries, which are more ſimple and perpendicular, or ſtraight, than in other parts. This medulla is more ſolid and more capable of ſuſtaining its figure, notwithſtanding it is very ſoft, and abounds in a greater quantity than that of the cortex. The greater poſterior branch of the carotid artery (§. 337.) firſt divides the right and afterwards the left hemiſphere of the brain into an anterior lobe, which is the larger, and a poſterior lobe, which is the leſs.

§. 359. The fabric of the cortex has been a long time controverted; but it is now ſufficiently evident, from anatomical injections, that much the greater part of it conſiſts of mere veſſels, which are every way inſerted from the ſmall branches of the pia mater, detached like little roots into the cortical ſubſtance, and conveying a juice much thinner than blood in their natural ſtate, although, in ſome diſeaſes and by ſtrangling, they often receive even the red parts of the blood, more eſpecially in brutes and birds. The remaining part of the cortex, which is not filled by any injection, is either an aſſemblage of veins, or of yet ſmaller veſſels; for no other diſſimilar parts are apparent in the cortex, whilſt it is in an entire or natural ſtate; from whence one may conjecture ſome part of it to be tubular, and the other part ſolid. As to glandules making the fabric of the brain, that notion has been diſcarded by univerſal conſent; nor indeed has there been any other opinion received with leſs probability than this.

§. 360. In order to gain a knowledge of the nature of the medulla, we are to conſider the anatomical ſtructure of this part of the human brain, compared with the brains of brute animals and fiſh. Therefore this part of the brain, which follows immediately under the outer gyri or convolutions of the cortex, is of a white colour, and becomes gradually broader and more abundant; ſo that, at length, it makes up the whole oval ſection of the brain, except only the gyri in the ſurface, which make the cortex. In this part, the two hemiſpheres of the brain, as before obſerved, are divided but half way through; which hemiſpheres (§. 358.) here continue their coheſion with the medulla in the middle. That part of the medulla, which is extended under the falciform proceſs, but at ſome diſtance from it, is called *corpus calloſum*, in the ſurface of which run two parallel white ſtripes. But the anterior extremity of this callous body is loſt in the ſubſtance of the crura, coming from the anterior lobes of the brain, as likewiſe are the poſterior crura with the foot-ſtalks of the hippocampus; moreover, the whole ſurface of this callous body is ſtreaked with tranſverſe fibres, which are continued, but extenuated into the next adjacent medulla of the brain itſelf.

§. 361. As to the remaining parts of the brain, a ſcrutiny is more difficult to be made into them; for the brain is not a ſolid body, but begins to be hollow internally from the lower part of its medulla, which is incumbent upon the multiform bone, at which place the greater crus of the brain paſſes out from it; and in this cavity, the medulla is only covered with the pia mater, which aſcends backward, and then turning continues its courſe forward and upward. Next, the brain divides itſelf near the poſterior extremity of its callous body, and, at the ſame time, ſends one of its ſhorter poſterior portions into the poſterior lobe of the brain, turning its extremity inward. But the anterior portion is continued a long way by the ſide of the callous body, parallel to the horizon, and turning its horn and end outward, it is terminated in the anterior lobe of the brain. This cavity, of which there is one in each hemiſphere of the brain, is called its triangular or anterior *ventricle*; and it is naturally filled with a vapour, which being frequently condenſed, puts on the appearance of water.

§. 362. This cavity is full without any intermediate ſpace by the cloſe meeting together of the ſides of the upper and lower medulla. The lower ſide or pavement of this part is variouſly figured. In its fore-part, it forms a horn, below which there is a hill moderately convex, and of conſiderable length, covered with a membrane that is extremely vaſcular, and being outwardly of an aſh or grey colour, is called the corpora ſtriata; becauſe inwardly they exhibit to the view white ſtreaks, intermixed with a good deal of the cortex. More inwardly and backward there are two other ſimilar hills of the medulla obſcurely ſtriated, but mixed, however, with ſome portion of the cortex, and ſo incumbent together, that, in their upper part, they frequently cohere; and theſe continuing their courſe through the horn of each anterior ventricle, deſcend to the baſis of the ſkull, and there generate the optic nerves, of which theſe are called the *thalami*. Betwixt the ſaid ſtriated bodies and thoſe thalami, lies an intermediate white and ſtreaked medullary portion, called the double ſemicircular center; and this, being extended into a medullary faſcia, is continued acroſs from the right into the left ſide. But then the corpora ſtriata chiefly join and compoſe the *crura* or footſtalks of the brain.

§ 363. It is to be obſerved, that the corpus calloſum medium projects or riſes up in the common axis or middle of thoſe ventricles. Behind, this body lies contiguous and incumbent on the fornix or arch; but before, there are two ſimilar medullary partitions, which deſcend from this body the whole length of the corpora ſtriata; and this part, which, in its middle, includes an anonymous cavity, goes under the name of *ſeptum pellucidum*. This ſeptum is continued to the *fornix*; that is to ſay, the four-horned medullary tracts, which took their anterior origin from peculiar mammillary protuberances in the crura of the brain, at the baſis of the ſkull behind the optic nerve, now concur, and by a meeting together of the anterior part of the brain in that place (§. 362.), do there unite into one trunk. This is incumbent upon an interval of the ſtriated bodies, and upon another interval of the thalami;

from whence it degenerates partly into a broad thin fimbria, and partly into another tubercle, which is continuous with the fornix and callous body of an half cylindrical figure, and furniſhed with an oppoſite *fimbria*. Theſe deſcend into the lower anterior horns of the ventricles, and at laſt terminate by a ſort of convex ſulcated end, imprinted by the cortex and named *pedes hippocampi*, which are outwardly medullary, inwardly of a cortical ſubſtance. A like protuberance is continued in the poſterior horn of the ventricle. Betwixt the departing crura of the fornix, the tranſverſe medullary portion, which is behind the middle plexus of the ventricles, and painted with ſtreakes, or palmated, is called the *pſalterium* or harp.

§. 364. Within the anterior or lower part of each of the ventricles, begins the vaſcular *plexus*, called *choroides*, included in the pia mater only, except which, it lies naked in the cavity of the ſkull, made up of a great many ſmall arteries (§. 337, 338.), together with little veins leading to the larger trunk (§. 346.); all which numerous veſſels, joined together by the pia mater, reſemble a curtain variouſly folded. With theſe are intermixed many ſmall pellucid glandules of a round figure, reſembling hydatids. When thoſe plexuſſes have reached the anterior extremity of the thalami, being afterwards reflected and united together, they gradually deſcend through the crevice of the third ventricle as far as the pineal glandule, where they terminate by the meeting of other veſſels (§. 338.), and then continue to inſinate themſelves within a large portion of the pia mater, to the lower part of the brain. From this plexus, doubtleſs, proceeds the internal warmth of the brain, with its exhalation and inhalation. [But the choroidal plexuſſes become very broad, where the anterior ventricles of the brain begin to deſcend, and thence, contracting gradually downward, they project their extremities to the ends of the anterior ventricles, covered only with the pia mater.]

§ 365. Betwixt the thalami, applied one to the other almoſt with a plain ſurface, there is a natural fiſſure terminating the crura of the brain, which meet together in the baſis of the ſkull, and this is called the *third ventricle*, which leads by a declivity, like a funnel, forward into the column of the medulla; which, though hollow in brutes, is yet evidently leſs tubular in man, and connected to the pituitary glandule (§. 356.). Backward, the thalami are conjoined together in the bottom of the ventricle by a medullary faſcia; but the ventricle itſelf, being inclined forward before the nates and teſtes, leads to the fourth ventricle. In this courſe, is extended round it a broad, ſhort, medullary faſcia, ſtretched out from the bottom of the right thalamus to the bottom of the left. But there are other fibres, which go inclined towards the right through the length of the thalami, and which likewiſe join the thalami together on each ſide behind the former tranſverſe faſciculus, and before the pineal glandule. Thoſe are generally aſcribed to the pineal glandule itſelf, with which they cohere either not at all, or by very ſhort productions.

§. 366. Again behind the thalami, thoſe tranſverſe figured eminencies of the medulla meet together, which conjoin the medulla of the right and left poſterior lobes of the brain. In this part backward are engraved or cut out four oval eminences, which are outwardly ſmaller, called the *nates* and *teſtes*, and which are of a ſubſtance inwardly cortical, but outwardly medullary. Upon theſe is ſeated a cortical glandule, ſomewhat oval and conical, ſpread with many ſmall veſſels, into which the choroide plexus here degenerates; and this has been celebrated by the name of *pineal glandule*. [Betwixt theſe four protuberances and the crura of the oblong medulla, paſſes a groove or channel in the ſame direction from the third to the fourth ventricle, manifeſtly open, and called the aquaduct.]

§. 367. The whole medulla of the brain is, in its lower part or baſis, collected together into two very thick compreſſed columns, diſtinguiſhed in their ſurface by a line running according to their length; and theſe have internally a cortical ſubſtance. Theſe, which are the *crura of the brain*, meeting together downward, are covered by the ſubjacent crura of the cerebellum, and are inſerted by apparent ſtrata of fibres into the pyramidal bodies of the medulla oblongata; and with the other deeper fibres, which ſeparate the inner tranſverſe fibres that come from the cerebellum from the preceding, meet together with the medulla cerebelli to make up the beginning of the medulla oblongata.

§. 368. The *cerebellum*, as it is leſs, ſo it is more ſimple than the brain. It has two lobes, but no where deeply parted, united above and below in their center to a ring of the ſame fabric with itſelf, called the *proceſſus vermiformis*. This part of the encephalon contains a great deal of the cortex, with a leſs proportion of medullary ſubſtance. And here likewiſe the cortex is placed in the circumference, but marked with gyri or convolutions, which are rather parallel to each other, ſo as to form circles; by which the ſmall lobules or portions are diſtinguiſhed, but not deeply, and afterwards ſend out each of them their medulla, which is, by degrees, ſo collected together in rays or branches, meeting in one trunk, that the whole reſembles the figure of a tree. This medulla collected together into the large crura of the cerebellum, terminates or goes off three ways; one part aſcends towards the nates, where it joins with the medulla of the brain; but the right and left parts of the medulla are conjoined to each other by tranſverſe ſtriæ behind the nates. Another portion deſcends into the ſpinal medulla, and terminates in peculiar protuberances, which are both anonymous, and have other cortical portions near them. A third portion, which is larger, and variegated internally with ſerrated lines of the cortical ſubſtance, goes tranſverſely downward under the crura of the brain, which it embraces, and by twice intermixing alternately with their tranſverſe medullary fibres (§. 367.), it is in a great meaſure confounded together with them.

§. 369. In this manner the *pons* is firſt formed almoſt of an oval figure, depreſſed in its middle, having tranſverſe fibres on all ſides; namely, from a conjunction of the crura of the brain deſcending above thoſe of the cerebellum, and paſſing out from the medulla of the brain tranſverſely near the cerebellum. Afterwards the *medulla oblongata*, continuous to the pons, being partitioned in its middle by a peculiar ſulcus, is internally variegated and ſtreaked with a ſubſtance like the cortex, and deſcends of a conical ſhape, inclined to the great foramen in the occiput. This medulla has two pair of tubercles before the pons; the outermoſt, from their figure, called *corpora olivaria*; and the innermoſt, *pyramidalia*; becauſe they leſſen downward like a cone, and theſe are immediately divided by a ſulcus, thro' which the pia mater enters. But betwixt the medullary worm-like proceſs of the cerebellum, is formed a cavity above the tubercles (§. 368.), where it grows broader of a rhomboidal figure, and is called the *fourth ventricle*, ſhut in its back-part by the valvula magna, or a medullary proceſs from the cerebellum, uniting the velum to the nates (§. 368.); being cut into the medulla oblongata, and anſwering to the canal that is covered by the nates and teſtes, called the aquaduct. In this laſt ventricle, as well as in the foregoing, is lodged the plexus choroides, only leſs in bulk, together with an upper ſulcus, called calamus ſcriptorius. Each of theſe ſulci or diviſions are continued down along the medulla ſpinalis, both in its anterior and poſterior ſide; and therein tranſverſe fibres are detached in its upper part from the right to the left ſide, both of the medulla oblongata and ſpinalis. [But two or three of the tranſverſe ſtreaks, that ariſe from eminences, which intercept a ſulcus, are inſerted into the ſoft part of the acouſtic nerve; and others of the ſame kind aſcend to the crura of the cerebellum.]

§. 370. All the medulla of the brain and cerebellum goes out from the ſkull, through particular openings towards certain parts to which it is deſtined. The ſmaller bundles of this medulla, we call *nerves*; but the larger, deſcending through the ſpine, we call the *medulla ſpinalis*, which is a continuation of that called oblongata (§. 369.). But the nerves, which are bundles of the medulla, and very ſoft in their origin, are compoſed of ſtraight parallel fibres in diſtinct threads. Theſe nervous cords, after they have gone forward ſome length, covered with the firm pia mater of a rediſh colour, are afterwards united into a more tough or permanent ſtring; and then going off from the brain, they haſten to their proper opening in the dura mater, and thence run down through the intervals of the channels formed by that membrane, 'till they meet with an opening in the ſkull, out of which they paſs through the membranous funnels of the dura mater. The nerve, having arrived without the ſkull, is commonly ſurrounded by the dura mater, ſo as to become very ſolid and firm. Thus it is in the optic nerve, in the fifth pair, and in others; but in ſome again there does not appear to be any dura mater ſurrounding the nerve, as in the olfactory nerves, in the ſoft portion of the auditory nerve, and the intercoſtal. The nerves now deſcend naked or leſs fenced betwixt the muſcles, detaching their cords or threads of which they are compoſed, and are ſtill made up of the medulla covered by the pia mater. Many ſmall threads of this kind are joined together into larger, by the union of the cellular ſubſtance that ſurrounds them, through which run many ſmall arteries and veins intermixed; and ſometimes fat itſelf is therein lodged. But, in general, the outer covering, common to the whole nervous bundle, is either derived from the dura mater, or, at leaſt, is a hard plate of the cellular ſubſtance, wherein all the ſmaller threads are contained and united into one nerve.

§. 371. It is a principle, in common, to all the nerves of the head, to ariſe and paſs out from the lower part of the medulla of the brain or cerebellum. The olfactory nerve ariſes with lateral fibres from the interval betwixt the anterior lobe of the brain, but with direct fibres from the medulla of the anterior lobe itſelf. A great part of the optic nerve ſprings from the thalami (§. 362.), but ſome part likewiſe from the medulla of the brain itſelf in the baſis of the ſkull near the mammillary protuberance. The third pair of nerves come from the medullary crura of the brain, behind the mammillary bodies or protuberances. The fourth from the medullary ſtriæ, which join the footſtalk of the cerebellum to the nates (§. 368.). The fifth ariſe plainly from the peduncles of the cerebellum itſelf. The ſixth out of a ſulcus (§. 368.), deep from the bottom of the pons betwixt that and the medulla oblongata. The ſeventh ariſes with one part ſofter from the medulla oblongata, and by two tranſverſe ſtriæ, from the fourth ventricle itſelf; and with another part harder from that portion of the crus of the cerebellum, which lies next the pons. The eighth nerve ariſes from the interval betwixt the olivary and pyramidal bodies or protuberances, and according to the obſervation of other eminent anatomiſts from the fourth ventricle likewiſe. The ninth ariſes from the corpora olivaria only. The tenth, by reaſon of its double root, is reckoned a nerve of the neck, going out with an arch, in company with the upper and lower adjacent nerve. There is, therefore, no nervous branch that ariſes properly from the cerebellum, unleſs it be the fifth; for the anterior nerves, the olfactories, optics, and third nerve come from the brain only; and all the reſt from thoſe parts, where the medulla, both of the brain and cerebellum, are conjoined together.

§ 372. The *ſpinal medulla* is a kind of medullary rope or appendix to the encephalon, continued down from the medulla oblongata, as low as the ſecond vertebra of the loins, where it terminates of a rounding conical figure. In the neck its anterior and poſterior ſides are flat, laterally convex, but in the back it is four ſquare. The pia mater is a proper integument to this part as well as to the brain, ſince it enters the ſpinal medulla deeply by each of the fiſſures (§. 368), and divides it almoſt into two. The cortical ſubſtance, which lies within it, is more obſcure than that of the brain. The larger anterior arteries paſs back to it from the vertebrals out of the ſkull, and deſcend down through the whole length of the pia mater, frequently double and parallel to each other, perpetually making alternate ſinous flexures, which form inoſculations with the vertebral arteries about each pair of nerves, likewiſe with the intercoſtal arteries and with the branches of thoſe belonging to the loins and ſacrum, 'till, at laſt, the anterior artery, covered with a peculiar coat from the dura mater, goes out and diſappears at the coccyx. In like manner, the poſterior arteries, which are leſs, ariſe and are diſtributed from the lower arteries of the cerebellum The ſpinal veins deſcend, together with the arteries, from the brain itſelf, ſending out branches, in like manner, on each ſide, which accompany the nerves like ſo many circular ſinuſſes, fixed in the dura mater, and correſponding to the number of the vertebræ, all which ſo communicate one with another, that each has, on all ſides, a direct conſent both with the uppermoſt and lowermoſt; and after having ſent out branches, that join the vertebral, intercoſtal, and lumbal veins, they unite with thoſe of the ſacrum. The uppermoſt of theſe ſinuſſes inoſculates with the anterior occipital ſinuſſes, (§. 352.)

§. 373. But there is another covering, not ſpread with any veſſels, which ſurrounds the ſpinal medulla looſely and at a diſtance, and is pretty firm, of a watry clearneſs, called *arachnoides*, and which being longer than the pia mater, is extended to the bottom of the os ſacrum, where the nerves, only deſcending from the medulla, are collected by it into a faſciculus. But in what manner it goes out, together with the nerves, has not been hitherto deſcribed.

§. 374. Laſtly, the *dura mater*, belonging to the ſpinal medulla, and continued from that of the cerebellum, ſurrounds the preceding arachnoides, like which it deſcends to the bottom of the os ſacrum, being larger at its beginning, at the bottom of the neck, and at the loins; but ſlenderer in the back, and, being connected ultimately by many filaments to the os ſacrum, it, at laſt, diſappears in a ſlender cone. As the nerves paſs out through this membrane, it gives them an external covering, and directly thickens or ſwells with them into a *ganglion*, or hard, oval, rediſh-coloured knot, in which the rectilineal courſe of the nervous fibres is interrupted. To this hard covering of the dura mater internally adheres a ligament denticulated at the interval of each of the nerves, which ariſes from the ſkull near the courſe or paſſage of the ninth pair of nerves, tying the arachnoides to the dura mater by triangular productions in each of the intervals of the nerves, and betwixt the anterior and poſterior bundles of the ſpinal nerves down to the bottom. Externally, there is a ſort of fat ſurrounds the dura mater, and alſo lines internally the covering of the vertebræ of the ſpine, which, by this means, is ſo adapted like a tube to the medulla ſpinalis, that the latter is not liable to be compreſſed, by the bending of it in any poſition.

§. 375. The fibres of the ſpinal medulla, in dropſical ſubjects and in brute animals, appear very diſtinct. Theſe medullary fibres go out from the whole anterior and poſterior ſides of this long appendix, after which the anterior cords are commonly wrapt up in the pia mater, in which they converge together like rays into a larger faſciculus, to which alſo join ſimilar threads in another bundle from the poſterior faſciculi joining together into one nerve, which paſſing out through the holes of the dura mater betwixt each of the vertebræ, compoſe the ſpinal nerves to the number of thirty, anſwering to the vertebræ. Among theſe, the ſpinal nerves of the neck are ſhort and ſtrong, eſpecially the lowermoſt; thoſe of the back are ſmall, and thoſe of the loins again, with the firſt pair of the ſacrum, are large. But the nerves of the ſacrum are ſmaller. Of theſe nerves, the longeſt are thoſe which go out thro' the loins and os ſacrum, ariſing within the back itſelf. Thoſe covered with their pia mater, accompanied with correſponding arteries, and included within the arachnoide capſule, form a rope of nerves, which is commonly called *cauda equina.*

§. 376. Thoſe nerves are afterwards diſtributed to all parts of the body in a manner very complex, and not here to be deſcribed. But we muſt not omit to obſerve, that all the ſpinal nerves, except one or two in the neck, have both an anterior and poſterior trunk, which paſs out together betwixt the vertebræ; and that the latter or poſterior being diſtributed to the muſcles, only the former ſend out nervous foot-ſtalks, which joining the other anterior and adjacent ſpinal nerves, and having given a ſmall circle that goes to the ſixth nerve of the brain, they form together one great ſource of the principal nerves belonging to the human body, which, communicating with almoſt all the other nerves of the whole ſyſtem, ſend out nervous branches to the heart and all the viſcera of the abdomen. This intercoſtal or ſpinal nerve forms as many ganglions as are equal to the number of its medullary roots, except where ſeveral of thoſe roots meet together into one ganglion; and thus it forms various knots or communications with the crural, brachial, and diaphragmatical nerves, alſo with the par-vagum and ninth pair of nerves. The other primary or capital nerve is the eighth or *vague nerve*, ariſing from the brain and joining itſelf to the intercoſtal in the bottom of the neck, in the thorax, and in the abdomen; this paſſes out of the ſkull in three cords, of which the larger ſends branches to the larynx, gula, lungs, and the cordiac plexus itſelf (§. 94.) to the œſophagus, ſtomach, and liver. The third of theſe is the *phrenic nerve*, ariſing from moſt of the lower nerves of the neck and arms, and ſometimes, being increaſed from the root of the ſpinal nerve, it deſcends by the ſide of the pericardium, and inſerts itſelf into the upper face of the diaphragm; but below it receives nerves from the great plexus of the intercoſtal nerve. Moreover, the *acceſſory nerve*, ariſing by many ſmall roots from the ſeven uppermoſt poſterior nerves at the neck, and from the medulla oblongata, joins the nerve of the eighth pair going back again into the ſkull, and ſeems, by this means, to make a conſent betwixt that important nerve and the ſpinal medulla. Laſtly, the nerves of the limbs have at their origin plexuſſes or knots, and are, on account of their length, harder or firmer in their ſubſtance, and much larger than the great nerves which go to the viſcera; thoſe of the arms, ariſe from the four lower nerves of the neck and firſt of the back; but thoſe of the lower extremity from the nerves of the loins and os ſacrum.

§. 377. The nerves divide into branches like the blood-veſſels, but in acute angles, and often in a courſe manifeſtly retrograde, growing gradually ſofter and leſs in bulk, 'till, at length, their ultimate extremities, which are ſeldom viſible, ſeem to terminate in a pulp, by depoſiting the firm integuments with which they were covered after the manner which we obſerve in the optic nerve. But the rectilineal courſe of the fibres, continued from the brain itſelf, is ſuch, that it is never broke off by the diviſion or ſplitting of a nerve into ſmaller threads, which only recede from each other by an opening of the cellular ſubſtance that tied them together. This appears from the diſorders, which are determined not to all, but only to ſome ſingle parts by injuries of the brain, as a loſs of the voice, deafneſs, dumbneſs and palſies of particular muſcles. They are connected in their courſe by the cellular ſubſtance to the adjacent parts, but have hardly any elaſticity; whence they do not fly back after being divided, but only expel, by the contraction of their integuments, the ſoft medulla, which they include. A great many nerves are ſent into the muſcles, many of them go to the ſkin, but fewer to the viſcera, and feweſt of all to the lungs. They make frequent inoſculations with each other like the blood-veſſels; and it is principally in theſe meetings of their branches, ariſing from different trunks that the nervous ganglia are formed; namely, hard nervous tumours, for the moſt part repleniſhed with blood-veſſels, and included in a firm membrane, but of a uſe and ſtructure as yet not certainly known. The nerves of the ſenſes only are excepted from theſe ganglia or knots; together with the eighth pair; but they ſeem in a manner eſſential to the phrenic nerves, to the fifth pair, to thoſe of the limbs, to the ſpinal and to the intercoſtal nerves, which laſt are truly ſpinal nerves.

§. 378. Thus far we are taught by anatomy concerning the brain and nerves; it remains from hence, that we explain the phyſiological uſes of theſe parts. Every nerve, therefore, that is irritated by any cauſe, produces a ſharp ſenſe of pain, and if the cauſe be great, thoſe muſcles, to which the primary or communicating nerve goes, become immediately agitated with a convulſive motion, which is ſtronger than their natural motion, and not governed or reſtrained by any power of the will. The ſame thing is likewiſe true after death, if the experiment be made ſoon after, as we ſee in the heart and other muſcles of brutes. (2). Any nerve being cut through, the muſcles, to which it is diſtributed, become paralytic and generally waſte away or wither in a ſlow manner. But if the nerve ſo cut performed any particular ſenſe, in that caſe, whether it be cut through or only compreſſed, the ſenſe is loſt; but by removing the compreſſure from the nerve, if the ſtructure of it was not ſpoiled by the ligature, the muſcles regain their ſtrength. All thoſe effects follow in ſuch a manner, that the parts, moſt remote from the brain, conſtantly ſuffer from the injury of the nerve, without any effect upon thoſe parts that are nearer to the brain. Experiments of this kind have been made upon the recurrent nerve, upon the eighth pair, and the phrenic nerve, with thoſe of the limbs; and laſtly, upon the lower dental nerve of the fifth pair.

§. 379. But the medulla of the brain, being vellicated or varioſly irritated, dreadful convulſions enſue throughout the whole, and this without any exception, whatever be the part of the brain ſo affected. The ſame conſequences alſo follow, if the ſpinal medulla be irritated. But if the encephalon itſelf be compreſſed in any place whatever, there follows thence a loſs of ſenſe and motion in ſome part of the body, which muſt be the part whoſe nerves are detached from the affected or compreſſed quarter of the brain. This is clearly evidenced from experiments, which have been made on particular parts of the brain diſordered; as from thoſe, for inſtance, in which the origin of the nerves are compreſſed, as in the optic nerves the ſight is extinguiſhed; as the hearing is, from a like affection of the auditory nerve, or as the motion of one arm or leg, or one ſide of the pharynx is aboliſhed by a compreſſure upon the roots of their nerves. But in the injuries of the ſpinal medulla, it is ſtill more evident, that thoſe parts, which receive their nerves ariſing from the place injured in the medulla, are either convulſed if that be irritated, or rendered paralytic if it be compreſſed. But when any more conſiderable or large portion of the brain ſuffers a compreſſure, either from blood, water, ſchirrus, an impacted bone or other mechanical cauſes, there follows perpetually either a diſturbance of all the faculties of the mind, or elſe a delirium, vertigo, madneſs, ſtupidity, or an incurable ſleepineſs; all which diſorders ceaſe upon removing the compreſſing cauſe. Laſtly, if the cerebellum, or the corpus calloſum, and more eſpecially the oblongated or ſpinal medulla, entering the neck, be injured in like manner, death immediately follows; becauſe, from thoſe parts, principally ariſe almoſt all the nerves of the heart, (§. 94.).

§. 380. Theſe things being conſidered, there ſeems to be no doubt, but the cauſe of all motion in the human body ariſes from the brain with its annexed cerebellum and ſpinal marrow; and that it thence proceeds through the nerves to all the muſcles and moveable ſolids of the body. The cauſe, therefore, of this motion cannot reſide or dwell in the parts themſelves, becauſe otherwiſe the moving cauſe would continue to act, after being ſeparated from the brain; nor would it be increaſed by irritating the brain, or weakened by a compreſſure of it.

§. 381. Nor is it leſs evident, that *all ſenſe* ariſes from an impreſſion of the ſenſible object upon ſome nerve of the body, through which nerve, the impreſſion being conveyed to the brain, when it is finally there arrived, repreſents ſome idea to the mind. It is, therefore, a falſe poſition, that the mind perceives immediately in the nervous branches or ſenſible organs themſelves; for this opinion is confuted by the pains, which a perſon will feel in a limb after it has been cut off, and from the interruption or removal of all pain by a compreſſure of the conveying nerve, with diſorders of the ſenſes from affections of the brain.

§. 382. Whether or no this faculty of perceiving impreſſed objects by the mind, and of uſhering out the motions, which follow either of neceſſity or from the will, be priviledged in common to the whole brain, cerebellum, and ſpinal medulla; becauſe in thoſe parts are formed the roots which are continuous with the nerves, remains a queſtion? but we are not to believe this from the many inſtances of wounds in ſeveral parts of the brain, from which the ſenſes have received no injury, neither from abſceſſes, which have largely waſted the lateral hemiſpheres of the brain, &c. From hence many queſtions may ariſe; as whether there be any principal or particular ſeat of the brain from whence all motion ſprings, and in which all ſenſation ends, ſo as to be the habitation or reſidence of the mind itſelf? and whether this part be not the corpus calloſum, becauſe wounds therein and the effects of diſeaſes are here more certainly and ſuddenly fatal? whether the ſaid corpus calloſum has a ſufficient communication or connection with the whole nervous ſyſtem for ſuch a purpoſe? whether there are truly any inſtances of the fifth, ſeventh, or other nerves, ariſing manifeſtly from this part? whether or no wounds of the ſpinal medulla are not equally or more fatal; when at the ſame time we know it is not the ſeat of the mind; becauſe, being compreſſed or deſtroyed, a perſon will ſurvive a long time with all his mental faculties entire? [Add, moreover, in oppoſition to this, that, in birds who have no corpus calloſum, wounds of the ſpinal medulla are equally fatal with thoſe in any other part of the encephalon.]

§. 383. Whether or no the ſeat of the mind is in all thoſe parts, which make the beginning of each nerve, in ſuch a manner, that the firſt originations of all the nerves conjunctly make together the true common ſenſory, where all the ſenſations are repreſented to the mind and all motions ariſe, whether neceſſary or voluntary? we muſt confeſs, that this is highly probable. For the origin of motion does not ſeem capable of ſpringing from any part below the ſource of the nerve; and it would be begging the queſtion, to ſuppoſe any part of the nerve, which is like the reſt in its fabric, to be either void of ſenſe or motion. Nor can the origin of motion (§. 380.) be placed higher than this; for ſo it will fall within the arteries, which have neither the faculty of ſenſation nor of voluntary motion; it, therefore, follows, that the ſeat of the mind, if it be material, muſt be where the nerve firſt begins its formation or origin.

§. 384. We come now to explain the manner in which the nerves become the organs of ſenſe or motion; which, as it lies hid in the ultimate elementary fabric of the medullary fibres, ſeems to be placed above the reach both of ſenſe and reaſon; but we ſhall, notwithſtanding, endeavour to make this as plain as experiments will enable us. And firſt, it is demonſtrated, that the nerves ariſe from the medulla of the brain, the truth of which is manifeſt to the eye in all the nerves of the brain, more eſpecially in the olfactory, optic, fourth and ſeventh pair of nerves, which continue their medullary fabric a long way before they put on the covering of the pia mater.

§. 385. We muſt, therefore, next enquire into this medulla, what it is. That the compoſition of it is fibrous or made up of parallel threads, diſpoſed longitudinally by the ſides of each other, appear from innumerable arguments, more eſpecially to the eye in the corpus calloſum, in the ſtriatum, and thalami of the optic nerves; but ſtill more evidently in the brains of fiſh. That the fibres of the brain are continuous with thoſe of the nerves, ſo as to form one extended and open continuation, appears, by obſervation, very evidently in the ſeventh, fourth and fifth pair of nerves.

§. 386. But here a controverſy begins concerning the nature of this fibril, which, with others of the like kind, compoſes the ſubſtance of the medulla and of the nerves. That this is a mere ſolid thread and only watered by a vapour exhaling into the cellular fabric, which ſurrounds the nervous fibres, has been aſſerted by many of the moderns.

§. 387. But we are not allowed to receive this opinion for the following important reaſons, which we here alledge. The cortex of the brain is, on all ſides, vaſcular, and coheres ſo manifeſtly, by an undivided and inextricable continuation with the medulla itſelf, that no one can either doubt or object againſt this truth. Moreover, the moſt conſiderable portion of the blood (§. 339.) is ſent up to this cortical part of the brain, to which the medulla is always proportionable, both in its growth and dimenſions. This being duely conſidered, I conclude, that the ſmall veſſels of the cortex, of which it is compoſed (§. 359.), are continuous with the fibres of the medulla, of which that part of the brain is wholly made up; and that, therefore, they cannot be ſolid impervious fibres, becauſe ſuch a fabric will occaſion the great quantity of juices, ſent to the cortex by the carotid and vertebral arteries, to return back uſeleſs, repelled from the ſolid medulla; again, from analogy, it follows, that the cortex, increaſing by growth proportionably with the medulla itſelf, it plainly appears, that they muſt have both one and the ſame common incrementive cauſe; which cauſe (by §. 249.) is the greater force of the heart, by which the blood-veſſels are elongated. It follows, therefore, that the medulla alſo muſt be compoſed of veſſels, which, in like manner, are diſtended by the ſame force of the heart.

§. 388. Nor is ſuch a ſolidity of the nervous fibres reconcileable with the appearances, which follow after wounds in the nerves. For if a nerve irritated required to be ſtruck, and to tremble like elaſtic cords, it ought to conſiſt of hard threads, ſtretched out and held faſt by their extremities to certain firm or ſolid bodies, with a conſiderable degree of tenſion; for cords, which are either unſtretched, ſoft, or not fixed or faſtened at their extremities, afford no ſound. But all the nerves are, in their origin, extremely ſoft, medullary, and very far from all tenſion; and ſome of them continue thus ſoft throughout the whole extent, ſo far as that goes, of which we have an example in the olfactory nerves, and in the ſoft portion of the auditory nerve, from which we ought more particularly to expect thoſe tremors, which reſemble ſound. Moreover, when the nerves are hard, they always grow ſoft afterwards in the viſcera, muſcles and organs of ſenſe, before they operate; and, therefore, the nervous fibres, being in no ſtate of tenſion, either in their beginning or ending, cannot be ſubject to elaſtic tremors. Even in thoſe moſt choſen and likely circumſtances, the nerves can have no tremors, where they are faſtened in a more tenſe manner to the heart, pericardium and great arteries; becauſe they are cloſely tied to the adjacent ſolid parts in their progreſs by the ſurrounding cellular ſubſtance. Finally, that the nerves are very far from all elaſticity, is demonſtrated by experiments, in which the nerves cut in two neither ſhorten nor draw back their divided ends to the ſolid parts, but are rather more elongated by their laxity, and expel their contained medulla in form of a protuberance. [Again the extreme ſoftneſs of the medulla in the brain, with all the phenomena of pain and convulſion, leave no room to ſuſpect any ſort of tenſion, concerned in the effects or operations produced by the nerves.]

§. 389. Add to this, that the force of an irritated nerve is never propogated upward, ſo as to convulſe the muſcles that are ſeated above the place of irritation, although the trunk of the nervous cord may happen to be firmer and tighter in that part; which is a conſequence altogether diſagreeing with elaſticity, whoſe tremors propogate themſelves in cords and other bodies every way from the point of percuſſion. Theſe arguments, therefore, ſerve to demonſtrate, that there is a liquor ſent through the brain, which, deſcending from thence through the nerves, flows out to all the extreme parts of the body; the motion of which liquor, quickened by irritation, operates only according to the direction, in which it flows through the nerve, ſo that convulſions cannot thereby aſcend upwards, becauſe of the reſiſtance made by the freſh afflux of the fluid from the brain. Nor is the experiment made upon the phrenic nerve without its force in this argument, by which it appears, that compreſſing the nerve with a motion downward, the contraction of the diaphragm is increaſed, but, by compreſſing the nerve upward, the motion ceaſes; from whence it is evident, that in the firſt caſe the natural courſe of the nervous liquid is quickened, and in the latter ſuſpended; nor can the nerves ever act as cords, when they never tremble by any preſſure, in whatever direction they may be urged by the finger.

§. 390. I believe it is, therefore, certain, that the nervous fibres are hollow, and perform their offices not by their elaſticity, but by the motion of their juice. Nor is the objection, which ariſes from the ſmallneſs of theſe tubes, not viſible by any microſcope of any force againſt the propoſed arguments; to which add the abſcence of a ſwelling in a tied nerve, which, in reality, is not ſufficiently true; with other arguments of the like kind, which, indeed,

deed, ſhow the weakneſs of our ſenſes, but have not any validity againſt the real exiſtence of a juice or ſpirit in the nerves.

§. 391. But concerning the nature of this nervous liquid, there are many doubts; for many of the moderns will have it to be extremely elaſtic of an ætherial or of an electrical matter; but the more reaſonable part make it to be incompreſſible and watry, but of a lymphatic or albuminous nature. Indeed, it is not to be denied, but we have many arguments againſt admitting any ſyſtem that has been hitherto advanced. An electrical matter is, indeed, very powerful, and fit for motion; but then it is not confinable within the nerves, ſince it penetrates throughout the whole animal, to which it is communicated, exerting its force upon the fleſh and fat, as well as upon the nerves. But in a living animal the nerves only, or ſuch parts as have nerves running through them, are affected by irritation; and, therefore, this liquid muſt be of a nature that will make it to flow through, and be contained within the ſmall pipes of the nerves.

§. 392. A watry and albuminous nature is common to moſt of the juices in the human body, and may be, therefore, readily granted to the juice of the nerves; like the firm ſerous water, which exhales into the ventricles of the brain from the ſame veſſels, alſo from the example of a gelatinous of lymphatic juice, which flows out in cutting through the brain in fiſh, and the larger nerves of brute animals, to which add the tumour, which ariſes in tied nerves. But are theſe properties ſufficient to explain the wonderful force of convulſed nerves, obſervable in the diſſections of living animals, and even in the leſſer inſects, with the great ſtrength of mad and hyſterical people? whether or no is not this difficulty ſomewhat leſſened from the hydroſtatical experiments of attraction in ſmall tubes? which, although it may explain the ſtrength and motion, is nevertheleſs inconſiſtent with the celerity.

§. 393. Therefore, upon the whole, it ſeems to be certain, that, from the veſſels of the cortex, a liquor is ſeparated into the hollow pipes of the medulla, which are continued with the ſmall tubes of the nerves, even to their ſoft, pulpy extremities, ſo as to be the cauſe both of ſenſe and motion; but the preciſe nature of this juice does not ſeem to be yet known. That it is extremely moveable, ſufficiently appears as well from the nature of the blood that goes to the brain (§. 339.) as from the effects or appearances which follow from it, and from the nature of tenuity itſelf, by which Sir Iſaac Newton has obſerved the powers of bodies are increaſed. But we muſt well diſtinguiſh this juice from that viſible thick liquor, which diſtils from the ſmall veſſels, which run in the cellular fabric betwixt the threads of the nerves.

§. 394. If it be aſked, what becomes of this nervous juice, which cannot but be ſeparated and diſtributed in great abundance from ſo large a quantity of blood, paſſing the brain very ſwiftly, in compariſon of the ſlower moving

ing blood, from whence the milk is ſeparated in the breaſt, and the urine in the leſſer renal artery, or by a compariſon with the meſenteric artery? it may be anſwered, it exhales probably through the cutaneous nerves; and ſome have judged, that it alſo exhales into the various cavities of the body, as that of the ſtomach, inteſtines, &c. but that it exhales into the blood-veſſels, does not ſeem very conſiſtent with the courſe of nature; although it may be ſuppoſed to be taken up by the leaſt abſorbing veins, which by degrees open into the larger. That thus it may be reſorbed from the cavities of the body, is not inconſiſtent. But whether it can return again within the ſame nerves to the brain, ſo that the nerves can reſemble arteries and veins as to the courſe of their ſpirits? or whether ſenſation ariſes from ſuch a return, are as yet mere conjectures?

§. 395. But then, what is the deſign of ſo many protuberances in the brain, what are the particular uſes of the ventricles, nates, and teſtes, with the diſtinction of the brain from the cerebellum, and the communication betwixt one ſide of the brain, cerebellum and ſpinal medulla, with their oppoſite ſides by ſo many tranſverſe bundles of fibres. Theſe ſtill remain to be determined.

§. 396. The ventricles ſeem to be made of neceſſary conſequence, and towards the greater uſe and diſtinction of the parts. And that the corpora ſtriata or thalami might keep their medullary parts from cohering one to another, it was neceſſary for a vapour to be poured betwixt them; and the ſame is true, with regard to the brain and cerebellum. Perhaps likewiſe the neceſſity of adminiſtring a degree of warmth to the cloſe medulla of the brain may be one reaſon for theſe cavities, by which the arteries enter, and are diſtributed in great numbers.

§. 397. The uſes of moſt of the protuberances we are not acquainted with, but have them yet to learn from diſeaſes, and from anatomical experiments made on animals, having a brain like that of mankind. But, in theſe reſpects, we have little hopes of ſucceſs, in parts that are ſo ſmall, ſo deeply, and ſo difficultly ſituated, and hardly ever to be approached, but by a wound ſoon fatal. Whether theſe parts are ſo many diſtinct provinces, in which our ideas are ſtored up; and whether this be confirmed by the protuberant thalami of the optic nerve, are, indeed, queſtions. But then moſt of theſe protuberances ſend out no nerves at all.

§. 398. As to the internal communication of one part with the other by ſtriæ or ducts; that ſeems to conduce to the advantage of motion, and probably of ſenſe likewiſe. Some of theſe communications join the brain with the cerebellum, others join the ſpinal medulla with the nerves of the brain itſelf, as in the acceſſory nerve, and moſt of them join the right and left parts together, as in the anterior conjunction before-mentioned (§. 362.), and in the two poſterior (§. 365.), in that of the corpus calloſum (§. 360.), in the ſtriæ, betwixt a proceſs of the cerebellum and teſtes (§. 368.);

to which add, the medullary croſs-bars in the medulla oblongata and ſpinalis (§. 369.). For, from this ſtructure, it ſeems manifeſtly to follow, as well as from numberleſs experiments and obſervations, that when the right ſide of the brain is injured, all the nerves, which belong on the contrary to the left ſide of the body, become diſeaſed or paralytic, and the reverſe. Moreover, by this contrivance, nature ſeems to have provided, that, in whatever part of the brain an injury may happen, the nerve, that ariſes from thence, is, by this means, not always deprived of its uſe. For if the ſaid nerve receives its fibres by communicating bundles, as well from the oppoſite as from its own hemiſphere of the brain, its office may, in ſome meaſure, be continued entire by the fibres, which it receives from the oppoſite ſide, even after thoſe of its own ſide are deſtroyed. Accordingly we have numberleſs inſtances of wounds, and with a conſiderable loſs of ſubſtance from the brain, which yet have not been followed with injury to any nerve, or to any of the mental faculties. [Many other leſs inequalities, ſtripes, protuberances, and nerve-like impreſſions appear in the brain from mechanical neceſſity, with the pulſation of the veſſels, and the preſſure or figure of the continous incumbent parts.]

§. 399. Whether or no there are diſtinct provinces for the vital or ſpontaneous, and for the animal or voluntary actions? and whether the cerebellum furniſhes the heart and other vital organs with nerves, while the brain ſupplies the nerves, which go out to the organs of ſenſe and voluntary motion? indeed, this, though an elegant ſyſtem, is every where confuted by anatomy. From the cerebellum, the fifth nerve is manifeſtly produced; but then this goes to the tongue, to the pterygoide muſcles, buccinators, temporals, frontals, muſcles of the outer ear, of the eye, and of the noſe, which are parts all of them either moved by the will, or elſe deſtined to ſenſation. Again, from one and the ſame nerve, as in the eighth pair, there are vital branches ſent to the heart and lungs, and others that are animal and voluntary to the larynx, or ſenſitive in the ſtomach. Laſtly, the repeated accounts of injuries to the cerebellum, being ſo ſuddenly and ſpeedily fatal, are not altogether true; for that both wounds and ſcirrhoſities of this part have been ſuſtained without any fatality to the patient, may be affirmed by certain experience, our own not excepted. [Nor is the difference of the brain, having a ſofter and finer texture than the cerebellum, any thing very conſiderable. But why does the brain appear itſelf inſenſible, and never tranſmit any preſſure upon it to the mind? for this plain reaſon, that all ſenſe is transferred to the mind, through the tubular medulla of the brain, which being either compreſſed, or otherwiſe occluded, no impulſion on the mind, even from its own preſſure, can be received into the intellect.]

§. 400. But if this elegant hypotheſis (§. 399.) be not true, you will ſay, what is the cauſe of the perpetual motion in the heart, inteſtines and other parts, which appear to want no inclination of the will to put them in motion and which, when in motion, are not governable by any power of the mind? why does the pulſation of the heart and arteries continue in an apoplexy after the nervous ſyſtem is eclipſed, from whence all the voluntary motions or ſenſes ariſe? indeed, the cauſe is ſo ſimple, as to be probably the occaſion of its being almoſt univerſally overlooked. It is a general principle with nature in the animal fabric, for thoſe organs to operate perpetually, which are moſt tender or irritable, which are moſt apt for motion, and which are, laſtly, under a perpetual ſtimulus or irritation. The heart then is continually provoked to action by the venal blood, which it expels (§. 112, 115.). The ſame is alſo ſo eaſily and apt to be put in motion, that it may be recalled even after death; its muſcular fabric is very ſolid and reticular, and its ſtrength very conſiderable; from all which, therefore, it is extremely moveable, and its irritability appears more eſpecially by the experiments before-mentioned (vid. §. 87.). Again the inteſtines alſo are extremely ſenſible; and, as will appear in their deſcription, full of nerves, and from the circular poſition of their fibres apt to contraction, as we ſee in all parts that have ſuch a diſpoſition of their fibres. And beſides this, they are almoſt perpetually irritated to motion, either by the chyle or aliments, by the confined air which they include, or by the bile ſent from the liver; to which add the preſſure of the hard fæces. With reſpect to the reſpiration, its perpetuity has been ſpoken of before, the alternation of which ſeems to me no otherwiſe explainable, than from the anxiety or uneaſineſs which follows both after inſpiration and expiration, which call both for a ſpeedy change. Vid. §. 293, 294, 298.

§. 401. We have before declared, that the nerves are the organs of ſenſe and motion; we ſhall, therefore, proceed firſt to explain that motion before we deſcribe the organs of ſenſe; becauſe it is more ſimple, uniform, and perpetually exerciſed, even in the fœtus before any of the ſenſes.

* * *

LECTURE XIII.

Of muſcular motion.

§. 402. BY the name of muſcular fibres in the human body, we call bundles of reddiſh coloured threads, which, by an approximation of their extremities, perform all the motions of which we are ſenſible. When many of theſe fibres are collected together, and appear more evidently red, they are called *a muſcle*. The extreme ſimplicity of the fabric in theſe parts has been the cauſe of the obſcurity that prevails in underſtanding, how a ſmall, ſoft, fleſhy portion can produce ſuch ſtrong and ample motions as we ſee in man, but more eſpecially in the cruſtaceous inſects.

§. 403. In every muſcle we meet with long ſoft threads or *fibres*, ſomewhat elaſtic or extenſible, and almoſt conſtantly diſpoſed parallel with each other; and theſe, being ſurrounded with a good deal of cellular ſubſtance, are by that faſtened together into little bundles. Thoſe bundles, called lacertuli, are again tied together into larger bundles, by a more looſe cellular net-work, which contains ſome fat; and betwixt theſe we conſtantly perceive membranous partitions and ſtripes of the cellular ſubſtance, removing them farther from each other, 'till, at laſt, a number of them, combined together in a poſture either parallel or inclined, are ſurrounded with a more thin and denſe cellular membrane, continuous with that of their partitions; and this being again ſurrounded by a thicker plate of the cellular ſubſtance, externally parts the whole from the adjacent fleſh, and gives it the denomination of a ſingle or entire muſcle. In every one of theſe threads there appears a leſſer ſeries of filaments, which, by oblique extremities, are cemented to others of the ſame kind forming together a larger fibre.

§. 404. The generality of the muſcles, but more eſpecially thoſe which are inſerted into the bones, and ſuch as are preſſed ſtrongly by other fleſhy incumbent parts, do not conſiſt of fibres altogether of one kind. For the fleſhy fibres (§. 403.), being collected together, cauſe the muſcle to be thicker in the middle, which is called its *belly*; and the ſame fibres, degenerating by degrees obliquely at each end of the muſcle into a more ſlender, hard and ſhining ſubſtance of a ſilver colour, change the nature of fleſh for that of tendon, in which, meeting cloſer together, the cellular ſubſtance interpoſed is thinner, ſhorter, and painted with fewer veſſels; whence it paſſes under the denomination of a *tendon*, by being collected together into a round ſlender bundle; or elſe, if it expands into a broad flat ſurface, it is called an *aponeuroſis*. For that the fleſhy fibres truly change into ſuch as are tendinous, is evident from comparing a fœtus (in which there are very few tendons) with a child of ſome years growth, in which there are many more; and both with an adult or old perſon, in which are the greateſt number. Muſcles, which are not inſerted into any of the bones, have commonly no tendons, as the ſphincters and muſcular membranes of the viſcera and veſſels. But thoſe commonly end in long tendons, which are required to paſs round the joints and heads of the bones, to be inſerted in thoſe extremities which are more moveable. In a fœtus, the muſcles are evidently inſerted into the perioſtium only; but in adults, where the perioſtium is more cloſely joined and incorporated with the bone itſelf, the tendons, being confuſed with the perioſtium, paſs together with that even into the foveoli of the bone.

§. 405. Within the cellular ſubſtance or membrane that ſurrounds the fibres, the arteries and veins are ſubdivided into net-works, which commonly form right angles, run in company, and moſtly contiguous with each other; and from the ſmaller of theſe veſſels a vapour is exhaled into the thinner cellular ſubſtance, as the fat is alſo transfuſed into the thicker cellular ſubſtance; from whence again they are both abſorbed. The lymphatic veſſels, which run betwixt the muſcles of the tongue, with thoſe of the neck, face and limbs, are difficultly demonſtrated. But there are alſo nerves more numerous than in other parts, diſtributed together with the blood-veſſels throughout the cellular fabric of the muſcle; which nerves, however, depoſite their harder covering, and become ſoft before they can be traced to their ultimate extremities in which they diſappear. Thoſe enter the muſcle in many parts, without keeping to the ſame place or ſituation; but in the tendons, they are very difficultly demonſtrated. Nor are there any nervous fibres inveſting the muſcular bundles or portions, ſo as to conſtringe them; for they, who have given ſuch a deſcription, have ſeen nothing but the cellular ſubſtance.

§. 406. The fabric of the leaſt, which are as the elements of a muſcle, being diveſtigated by the microſcope in man and other animals, has always appeared ſimilar to the fabric of the larger fibres; nor do they yield any other appearance, upon which we can rely, than that of the leaſt threads joined one to the other by the intermediate cellular ſubſtance. There is, therefore, no foundation here for a ſeries of veſicles, nor for a chain of rhombs. It may be aſked, whether theſe fibres are hollow, whether they are continued with the arteries? or whether the difference betwixt muſcular and tendinous fibres lies in the latter, being rendered more denſe and beat cloſer together by an expulſion of the fluids? that theſe are not probable, appears from the minuteneſs of the fibres, which are found leſs than the red blood-globules, and from the whiteneſs of a muſcle after the blood is waſhed out of it; to which add the phyſiological reaſons following, (§. 411.).

§. 407. It is natural to every muſcle to ſhorten itſelf, by drawing the extremities towards its belly or middle. But to diſcover the moving power of a muſcle from the fabric, which we have deſcribed, it will be of uſe to conſider the appearances, obſervable in muſcular contraction.

traction. Every muſcle then becomes ſhorter and broader in its action; but this contraction of its length is various, in ſome more, in others leſs, and is very conſiderable, for example, in ſome of the ſphincters, inſomuch that they appear to be contracted more than one third of their extent, though this computation be taken from an erroneous hypotheſis. At the ſame time that the muſcle is broader, it alſo becomes harder, and every way extended throughout its whole circumference; as for example, in the heart, in the maſſeters. Moreover, this motion in a living animal is made with a convulſive ſwiftneſs, while the fibres and muſcular portions are drawn out of their ſimple rectilineal courſe into undulated wrinkles, which are formed as well in the elementary ſimple fibres, as in the more compound lacertuli or bundles; wherefore the motion of every muſcle lies in a retraction of the fibres within themſelves, which being alternately more or leſs contracted, increaſe or diminiſh the length and breadth of any interval betwixt the points of contraction. I obſerve alſo, that the larger muſcular portions themſelves are drawn out of their courſe, ſo as to form different angles with each other, and with the bones which they move; and in general, right angles are changed into ſuch as are unequal; but that the muſcles grow pale in their action, does not appear in all my experiments.

§. 408. Moreover, that we may diſcover the cauſe of muſcular motion, we are to obſerve, that in every muſcular fibre, even after death, there is a force or endeavouring to contract its length, by which, being left to itſelf, it becomes ſhorter; and from hence, muſcles, that are divided even in a dead body, recede by contracting from each other, ſo as to leave a conſiderable interval. [Again, the parts of a moving fibre, being agitated or *irritated* by any force, which we call a ſtimulus, whether cold, puncture with the knife, acrid poiſons, &c. does immediately exert a vital corrugation, or contraction, different from the former dead one, of elaſticity, ſo long as the vital or locomotive, but unknown, diſpoſition of its parts remains, even after death; by which irritation, we obſerve, it will palpitate for a time, by alternately corrugating and elongating itſelf. This faculty of irritability is never obſerved to reſide in any part of the cellular ſubſtance; nor in membranes, ſo far as they are, in a great meaſure, compoſed out of that ſubſtance; in ligaments it is ſcarce obſervable in any degree, and in tendons it is extremely weak: but in muſcles, more eſpecially thoſe of the heart and inteſtines, it reſides in a moſt remarkable degree, ſo as to be ſuſceptible of irritation and contraction longer than in any other parts of the dying animal, and even for many hours after death; and in theſe parts too, the action is more violent in proportion, as the faculty or power longer remains, and is more eaſily excited than in other parts. It muſt be alſo confeſſed, that the evulſion of a muſcular irritable part out of the animal body, ſo as to cut off all union with its nerves, and intercept all intercourſe betwixt itſelf and the brain, does not much abate the irritable faculty and contractile force of the part, more eſpecially in the heart and inteſtines. That this irritable power of corrugation or contraction prevails largely, throughout all the animal fibres that are motive, appears plainly from the obſervations made upon the polype and other ſimilar inſects; which, being formed without either brain or nerves, are nevertheleſs extremely motive and impatient of all ſtimulus. Add to theſe, ſhell-fiſh and the analogy of ſome plants, whoſe flowers and leaves move their places, by expanding or contracting with heat or cold, and ſome of them with a ſort of ſenſative celerity, not inferior to that of animals. This force is, therefore, a new and hitherto neglected principle, different from the other known properties of bodies, and is not like them to be accounted for, either by gravity, attraction, or elaſticity; but depends upon an unknown diſpoſition of the parts in a ſoft moving fibre, which looſes this force as it hardens and dries. See remark to §. 6.]

§. 409. But that the cauſe of motion is conveyed through the nerves into the muſcles, is certain from the experiments before-mentioned (§ 378.). Namely, a nerve or the ſpinal medulla, being irritated in an animal, even ſoon after death, the muſcle or muſcles, which are ſupplied in branches from that nerve, become languid or paralitic, ſo as not to be able to move or to be recalled by any force to vital action. But if the ligature be taken off from the nerve, the force, by which the muſcle is put into action, is again recovered by it. This appears from numerous experiments, more eſpecially upon ſuch as have been made upon the phrenic and recurrent nerves. Alſo by irritating any nerve before you cut it, the muſcle, to which it goes, contracts, as you may learn by repeated trials, eaſily to be made on the limbs or extremities. Moreover, the weight, which is raiſed by a living muſcle, breaks or tears one that is dead; whence it appears to be greater than the inherent cauſe of contraction in a muſcle, by which, when living, the weight was raiſed.

§. 410. If it be demanded, whether the arteries conduce any thing to muſcular motion? and whether the palſy, which falls upon the lower limbs, after a ligature upon the aorta, be not an argument thereof? we anſwer, not at all, further than as they conduce to the integrity of a muſcle or to the conſervation of the mutual ſtructure and habit of the parts, which they ſupply with vapour, fat, &c. for the irritation of an artery does not affect or convulſe the muſcle to which it belongs, nor does a ligature thereof cauſe a palſy, unleſs after a conſiderable time, when the muſcles begin to be deſtroyed by a gangrene; and the palſy of the lower limbs from a ligature of the aorta belongs to an injury or loſs of the integrity of the ſpinal medulla. Moreover, it is impracticable to explain the motion of peculiar muſcles from a cauſe derived with an equal force from the heart to all parts of the body; and again, the influence of the will is confined to the nerves, without reſiding in the arteries or other ſolid parts of the body.

§. 411. But the direct manner, by which the nerves excite motion in the muſcles, is ſo obſcure, that we may almoſt for ever deſpair of its diſcovery. As to nervous veſicles ſwelling by a quicker flux of the nervous ſpirits, they are inconſiſtent with anatomical truth, which demonſtrates the leaſt viſible fibres to be cylindrical, and in no part veſicular, and likewiſe repugnant to the celerity with which muſcular motion is performed, and with the bulk of a muſcle being rather diminiſhed than increaſed during its action. Again, the inflation of rhomboidal chains in the fibres is equally repugnant both to the celerity, to inſpection, and to anatomy. Finally, it is, by no means, demonſtrable, that the fibres, from ſo few nerves, can be ſo numerous, or diſtributed in ſo many different tranſverſe directions, with reſpect to the muſcular threads, as thoſe hypotheſes require to be allowed. A complication of the nerves round the extremities or fibres, ſo as to contract them by their elaſticity, is founded upon a falſe ſtructure of the muſcular fibre, ſuppoſing the nerves to be diſtributed, where filaments of the cellular ſubſtance only can be demonſtrated. [Moreover, the experiments on animals (§. 488.), which, having neither brain or nerves, are yet very apt for motion, apparently demonſtrate the intrinſic fabric of the muſcles to be ſufficient for their motion, without other aſſiſtance from the nerves.] Other explanations, derived from ſpherules full of air in the blood, ſuppoſe a falſe nature of that fluid; namely, a repletion of it with elaſtic air, of which it has none, (§. 306.)

§. 412. This only we are certain of, from what has been advanced, that the nerves act not by their mechanical contraction, which is extremely weak, but by the power of an influent liquid, detached, or ſome way actuated, with great celerity. That muſcle, therefore, will be contracted, to which more nervous liquid arrives in a given time, whether that be from any impulſe of the will or other cauſe reſiding in the brain, or elſe from the power of ſome ſtimulus in the nerve itſelf. [Now whether the nervous liquid only increaſes the irritable nature, or elſe augments barely the inherent corrugating force of the conſtituent parts in the moving fibre, after a manner unknown to us, we ſee, in either caſe, that the conſequence is a ſhortening of the fibre or muſcle.] More than this, I am not able to perceive. The ſame muſcle is again relaxed, when this additional celerity in the motion of the nervous fluid is abated, and ſends it only in ſuch a quantity as will make an equilibrium.

§. 413. The effect of motion in the muſcles is a contraction or ſhortening of them, by drawing their tendons almoſt quieſcent each way towards their middle or fleſhy belly, by which means the bones and other parts, in which the tendons are inſerted, are brought together in the ſame manner as when a muſcle cut out of the body, contracts or draws its two extremities towards the middle part or belly.

But if one of theſe extremities be leſs moveable or more fixed; then, that which is more moveable has a greater motion towards that which is more fixed, in a proportion inverſely as their mobility. If one end be immoveable, then the other, which is moveable, is alone brought towards it; and, in this ſenſe, the diſtinction of origin and inſertion of the muſcles is allowable; otherwiſe, without this limitation, it may be frequently the cauſe of error.

§. 414. The ſtrength of this action in the muſcles is very conſiderable in all perſons, but more eſpecially in thoſe who are phrenetic, and ſome who are called ſtrong men; ſince frequently, with the uſe of a few muſcles only, they will eaſily raiſe a weight equal to, or much greater than, that of the whole human body itſelf. Notwithſtanding this, we ſee, that much the greater part of the force or power, exerted by a muſcle, is always loſt without producing any viſible effect. For all the muſcles are inſerted nearer the point or center of motion, than the weights they are applied to; and therefore their action is weaker, in the ſame proportion, as they move a ſhorter part of the lever, than that to which the weight is applied. Moreover, in moſt of the bones, eſpecially thoſe of the limbs, the muſcles are inſerted at very acute angles; whence again the effect, which a muſcle exerts in action, is proportionably leſs, as the ſine of the angle, intercepted betwixt the bone and the muſcle, is leſs than the whole ſine. Again, the middle part of all muſcular force is loſt, becauſe it may be reckoned as a cord extended, and drawing an oppoſite weight to its fixed point. Again, many of the muſcles are ſeated in the angle of two bones, from one of which ariſing they move the other; and, therefore, that bone being moved, they are bent, and, of courſe, like an inflected cord, require a new force to extend them. Many of them paſs over certain joints, each of which they bend in ſome degree, whereby a leſs part of their remaining force goes to bend the joint to which they are particularly deſtined. The fleſhy fibres themſelves of the muſcles frequently intercept angles with the tendon, in which they terminate; from whence a great part of their force is loſt, as much as is equal to the difference or deviation betwixt the ſine of the angle of their inſertion and the whole ſine. Finally, the muſcles move their oppoſed weights with the greateſt velocity and expedition, ſo as not only to overcome the equilibrium, but likewiſe to add a conſiderable celerity to the weight.

§. 415. All theſe loſſes of power being computed, make it evident, that the force, exerted by muſcles in their contraction, is exceeding great beyond any mechanical ratio or proportion whatever; ſince the effect is ſcarce $\frac{1}{60}$ of the whole force exerted by the muſcle, and yet only a ſmall number of theſe muſcles, weighing but a few pounds, are able not only to raiſe ſome thouſands of pounds, but alſo with a conſiderable celerity. Nor is this to be reputed any defect of wiſdom in the creator.

For all thoſe loſſes of power were neceſſary towards a juſt ſymmetry or proportion of the parts, with the various motions and celerities required by the muſcles to act in different directions; all which have no ſhare in the compoſition of engines mechanically. But we may, however, conclude from hence, that the action of the nervous or animal fluid is very powerful (§. 392.), ſince, in an engine ſo ſmall, it can exert a force equal to ſome thouſand pounds for a conſiderable time, or even for many days together; nor does this ſeem to be otherwiſe explainable, than by the incredible celerity, by which the influx of this fluid obeys the command of the will. But how, or from whence, it acquires ſuch a velocity, is not in our power to ſay; 'tis ſufficient, that we know the laws of its motion are ſuch, that a given action of the will produces a new and determinate celerity in the nervous fluid or juice.

§. 416. The eaſy and ſudden relaxations of muſcles in their motion are aſſiſted by the actions of their *antagoniſt* muſcles. Namely, in all parts of the body every muſcle is counterpoiſed by ſome weight, elaſticity, an oppoſite muſcle or a humour acting againſt the cavity of a muſcle, by which it is expelled. This oppoſite cauſe, which ever it be, continually operates as long as the muſcle acts, and, ſo ſoon as the additional celerity, derived from the brain, abates, it reſtores the limb or other part immediately to its former eaſy ſtate, in which there is an equilibrium betwixt the muſcle and its oppoſing cauſe. Whenever the antagoniſt power is removed

moved from the muſcle, there are none of them but muſt contract, extending their oppoſites, by which the diſtended nerves excite an uneaſy ſenſe, and cauſe a ſtronger endeavour towards recovering the equilibrium. Hence one of the flexor muſcles, being cut in two, the extenſor contracts or operates even in a dead body, and the reverſe.

§. 417. But there are other means, by which the motions of the muſcles are rendered more ſafe, certain and eaſy. The large long muſcles, by which the greater motions of flexure are performed, being included in tendinous capſules or caſes, drawn and tightened by other muſcles, are thus ſecured and ſtrengthened; for ſo the muſcle remains preſſed againſt the bone, in a ſtate of contraction, all the time that the limb is bent, and avoids a conſiderable loſs of its power. But the long tendons, which are incurvated or extended over joints in their motion, are received and confined by peculiar bands, which retain them within their ſlippery channels, and keep them from ſlipping out under the ſkin, which diſlocation of the tendon, whenever it happens, is attended with a cramp of the muſcle, ſevere pain and loſs of motion. The ſame kind of guidance or direction is received by ſome of the muſcles, which perforate others in their courſe. In other parts, the tendons are either carried round certain eminencies of the bone, in order that they may be inſerted at greater angles into the bone, which they move, or elſe they are inſerted into another bone; from whence a difherent tendon deſcends under a larger angle into the bone to be moved. In other parts, the muſcles, which are derived from convenient ſituations, have their tendons carried round in a contrary direction by nature, ſo that they paſs into the part to be moved, as it were round a pully. Nature has likewiſe ſurrounded the muſcles on all ſides with fat, which is ſpread alſo betwixt their bundles of fibres and the ſmall fibres themſelves which lie contiguous together; which fat, being preſſed out by the turgeſcence of the muſcles and fibres, renders them ſoft, flexible, ſlippery, and fit for motion.

§. 418. Moreover, the power and action of one muſcle is determined by the co-operations or oppoſitions of others, which ſerve either to hold firm ſome part from whence the muſcle ariſes, or to bend it together with the muſcle, or elſe to change its action from the perpendicular to the diagonal, by concurring to aſſiſt its force at the ſame time. Therefore, the action of no one muſcle can be underſtood from conſidering it alone, but all the others muſt likewiſe be brought into the conſideration, which are either inſerted into the muſcle itſelf, or into any of the parts to which the ſaid muſcle adheres.

§. 419. By theſe muſcles, variouſly conſpiring and oppoſing each other, are performed walking, ſtanding, flexion, extenſion, deglutition, and all the other geſtures and offices of the ſeveral parts in the living body. But the muſcles have likewiſe ſome common or public actions, by which they are of uſe to the whole

animal

animal. They haſten the return of the venal blood, by preſſing it out from the veins, both of the muſcles themſelves as well as of the veins which lie betwixt them; for the blood in theſe veſſels, diſtributed betwixt the turgid bundles of a contracted muſcle, is, by the valves, determined towards the heart only; they likewiſe return the fat to the blood, ſhake, grind, or denſify the arterial blood, and return it quicker to the lungs. Again, in the liver, meſentery, womb, &c. they promote the courſe of the contained blood, bile and other juices, ſo as to leſſen the danger of their ſtagnation; they ſerve alſo to increaſe the ſtrength of the ſtomach, by adding their own ſtrength to it, whereby digeſtion is promoted, inſomuch that all ſedentary and inactive courſes of life are contrary to nature, and pave the way to diſeaſes from a ſtagnation of the humours, or from a corruption or crudity of the aliments. But by too much exerciſe or action, the muſcles themſelves grow hard and tendinous on all ſides, render the parts, upon which they are incumbent cartilaginous, or elſe change thoſe, which are membranous, into a bony nature; at the ſame time they increaſe the roughneſs, protuberances and proceſſes of the bones, flatten their ſides which lie next to them, and dilate the cells ſeated in the diploe or ſpungy heads of the bones themſelves towards their ſtronger action.

§. 420. The muſcles are commonly diſtinguiſhed into claſſes according as they either reſt ſpontaneouſly, or are put into action by an inclination of the will; whence they are called voluntary and involuntary, while others are mixed. Some of them operate ſpontaneouſly, and can neither be excited nor retarded by the will, as in the heart and inteſtines; and ſome again are ſubſervient to a mixed power, as they operate by a ſpontaneous motion, and are likewiſe governable by the will at the ſame time, as in the muſcles of reſpiration. There have been various cauſes aſſigned for this difference; but I think the queſtion has been ſufficiently anſwered before at §. 400.

The End of VOL. I.

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Haller
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